WELL-SINKING

A SELECTION FROM WEALE'S SERIES.

SANITARY WORK IN THE SMALLER TOWNS AND IN VILLAGES. Comprising:—1. Some of the more Common Forms of Nuisance and their Remedies; 2. Drainage; 3. Water Supply. A useful book for Members of Local Boards and Rural Sanitary Authorities, Health Officers, Engineers, Surveyors, Builders, and Contractors. By CHARLES SLAGG, A.I.C.E. 2s. 6d.; cloth boards, 3s.

WELL-DIGGING, BORING, AND PUMP WORK. By JOHN GEORGE SWINDELL, R.I.B.A. New Edition, revised by G. R. BURNELL, C.E. Illustrated. 1s. 6d.

PIONEER ENGINEERING. A Treatise on the Engineering Operations connected with the Settlement of Waste Lands in New Countries. By EDWARD DOBSON, Assoc. Inst. C.E. 4s. 6d.; cloth boards, 5s.

ROADS AND STREETS (THE CONSTRUCTION OF). In Two Parts. I. The Art of Constructing Common Roads. By HENRY LAW, C.E. II. Recent Practice in the Construction of Roads and Streets: including Pavements of Stone, Wood, and Asphalte. By D. KINNEAR CLARK, M.I.C.E. With numerous Illustrations. 4s. 6d.; cloth boards, 5s.

THE SLIDE RULE, AND HOW TO USE IT: containing full and easy Instructions, by C. HOARE, C.E. With a Slide Rule in Tuck of Cover. 3s.; cloth boards, 3s. 6d.

DICTIONARY OF TERMS used in Architecture, Building, and Engineering; Mining, Surveying, and Construction; Early and Ecclesiastical Art; the Fine Arts, &c. New Edition, revised and enlarged by ROBERT HUNT, F.R.S. 5s.; cloth boards, 6s.

DRAWING AND MEASURING INSTRUMENTS. Including—I. Instruments employed in Geometrical and Mechanical Drawing, and in the Construction, Copying, and Measurement of Maps and Plans. II. Instruments used for the purposes of Accurate Measurement, and for Arithmetical Computations. By J. F. HEATHER, M.A., late of the Royal Military Academy, Woolwich, Author of "Descriptive Geometry," &c., &c. Illustrated. 1s. 6d.

OPTICAL INSTRUMENTS. Including (more especially) Telescopes, Microscopes, and Apparatus for producing copies of Maps and Plans by Photography. By J. F. HEATHER, M.A. Illustrated. 1s. 6d.

SURVEYING AND ASTRONOMICAL INSTRUMENTS. Including—I. Instruments used for Determining the Geometrical Features of a portion of Ground. II. Instruments employed in Astronomical Observations. By J. F. HEATHER, M.A. Illustrated. 1s. 6d.

MATHEMATICAL INSTRUMENTS. By J. F. HEATHER, M.A. Enlarged Edition, for the most part entirely re-written. The 3 Parts, as above, in One thick Volume. With numerous Illustrations. 4s. 6d.; cloth boards, 5s.

RUDIMENTARY TREATISE

ON

WELLS AND WELL-SINKING

BY JOHN GEO. SWINDELL, A.R.I.B.A.

AND

G. R. BURNELL, C.E.

AUTHOR OF "RUDIMENTS OF HYDRAULIC ENGINEERING," ETC. ETC.

With Illustrations

REVISED EDITION, WITH A NEW APPENDIX ON THE QUALITIES OF WATER

LONDON
CROSBY LOCKWOOD AND CO.
7, STATIONERS' HALL COURT, LUDGATE HILL
1883

CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

PREFACE TO THE SECOND EDITION.

The premature decease of Mr. J. G. Swindell, at the commencement of a promising career, has prevented the subsequent editions of his useful work from receiving the benefit of his care, or from recording the results of his more extended observations.

It was with considerable hesitation that I undertook to revise the work, because at all times it is a matter of delicacy to alter, or correct, the productions of a professional brother: it was especially so in this instance from the sad circumstance of Mr. Swindell's death. Moreover, on some points of detail, I did not entertain the same opinions as Mr. Swindell; on others the limits of our knowledge have been extended since his decease, by the researches of scientific men both at home and abroad, and by the results obtained in the numerous works executed in different parts of the country, so that forcedly this treatise is to a great extent altered from the one he left.

The objects I proposed to myself were precisely the same which Mr. Swindell stated to have guided him in writing the original Treatise; viz., to condense in a general practical manner many subjects connected with Well-work. As he said, "It would have been easy to enlarge upon any of them, but to have done so would necessarily have entailed a corresponding loss of matter in reference to the others. To avoid this on the one hand, and a mere superficial uninstructive glance on the other, has been the Author's aim. In furtherance of this object, the remarks on executed

work have been added. These precedents show, at a glance, methods of detail and arrangement which, if remarked on generally, would occupy much greater space; they also form a nucleus for observations which could only be brought forth by a long process of reasoning in any other manner. Again, they serve to bind and connect together, by their very particularity, considerations which otherwise might pass unheeded, on account of their now apparent applicability." In the second edition a modification has been made in the descriptions of these works by suppressing some, and introducing others. It might have been objected to those originally inserted that they were nearly all confined to the practice of the neighbourhood of London, and it appeared therefore advisable to introduce in a work of such general circulation illustrations of the course followed and the results obtained under a greater variety of circumstances.

I have, in this edition, endeavoured to preserve as much as possible the text as it was left by Mr. Swindell, merely altering what appeared to me the faults of composition. The spirit I have endeavoured to retain, the letter only has been modified. The alterations are, however, extensive—and indulgence is craved for them on the score of the difficulty which always exists in a second party's placing himself in the same position and in viewing a subject from the same point of view as the person who has gone before him.

More copious information upon the subjects treated of in the following pages may be found in the communications of the Abbé Paramelle, M. d'Archiac, M. Hericaut de Thury, M. Garnier, and M. Emery, to the different scientific publications in France; in the more decidedly practical works of M. Degousée and A. Burat, from both of which we have borrowed largely. In the "Traité des Irrigations" by Nadault de Buffon, much valuable information will be found with respect to shallow springs. In our own language we can hardly cite any other work than Mr. J. *Prestwich's* "Treatise on the Water-bearing Strata of

London;" but it is a host in itself, and contains proof of a skill, judgment, and careful observation, which justify our regarding it as a model of practically applied science. From the detached papers by Mr. Clutterbuck and Mr. Dickinson, in the Reports by Messrs. Stephenson and Homersham, much valuable information may be obtained; as also occasionally from the Reports of the Superintending Inspectors of the Board of Health, although the inferences drawn by the latter are always to be received with caution.

The reader who would desire to study the physiological influence of potable waters—a branch of the investigation which has only of late attracted public attention in our own country—is referred to the writings of Hippocrates, who knew quite as much, if not more, of the subject than some of our modern authorities. In Thénard's Chemistry; in the Dictionnaire des Sciences Médicales; in Haller's Elementa Physiologiæ; in a "Traité des Eaux Potables," by M. J. F. Terme, of Lyons; in some communications to the Académie des Sciences by Messrs. Chossat, Dupasquier, Berthollet, l'Héritier, and Tissot; and in the communications of Dr. Angus Smith to the British Association, and in the Report of the last Commission named by Sir G. Grey to examine into the qualities of the London waters,—much valuable information will be found upon the subject. It is worthy of remark that the Report of the last-named Commission is directly in opposition to the doctrines which the Board of Health have sought to inculcate with respect to the qualities of water; and in this it is perfectly in accordance with all that has been stated by physiologists from the time of Hippocrates to the present day. All, or nearly all, authorities of any value agree in considering that waters holding the bicarbonate of lime in solution are the most wholesome. It appears also that the rule sought to be laid down, that "the nearer the source the purer the spring," is very far from being of universal application, and that great danger is attached to the system of storing water in reservoirs. Such discussions are perhaps out of place in

works like the present, but it is important that the public should be made aware that the theories lately propounded are far from being received by scientific men.

The whole question of the physiological action of water is very ably treated in a "Traité d'Hygiène Publique," by Michel Levy.

GEO. R. BURNELL.

LONDON, 1851.

PREFACE TO THE REVISED EDITION.

THE alterations effected in this Edition are very few, being principally verbal corrections in places where the meaning was obscure. While making these, every care was taken to avoid nullifying any intentional expression of Messrs. Swindell and Burnell. The matter has, however, been rearranged in several places, and some portions of the old text removed. The principal addition consists in a new chapter (No. VII.), written by Mr. Burnell, but now appearing for the first time. The other additions made have, with the exception of a few extra lines in a few places, been put in an Appendix, and are thus markedly separated from the original text, so that the responsibility for the several parts is distinct.

L. J.

LONDON, *June* 23, 1882.

WELLS AND WELL-SINKING.

CHAPTER I.

PRELIMINARY OBSERVATIONS.

The practice of obtaining water from wells is of great antiquity. In the Hebrew Scriptures, the earliest record of the human race, many instances are cited of the importance attached to them in the burning plains of Syria, where, from the accounts handed down to us, they appear to have been mere excavations in the sides of rocks and hills in which springs of water were plentiful, the water rising so near the surface as to be reached by a bucket attached to a short rope. In Greece, this plan for raising water was common, and in many cases the orifice of the well was finished by a cylindrical curb of marble, which was sometimes beautifully carved.

The method of boring for water is of an antiquity very nearly as great, although the precise epoch of its introduction is unknown. In Syria and Egypt, it is reported that many fountains fed by waters obtained in this manner exist, and that the greater number of the oases of the Libyan chain owe their existence to similar works. M. Degousée mentions that he delivered to the Pacha of Egypt a set of tools for the purpose of reopening some of these wells, whose original construction probably dated some 4 000 years back; and when the works were completed, it was found that the wells were lined with brick or wood. The

details of the method used in sinking these wells are not known.

In China, however, the system of boring is ascertained to have been long practised, and a French missionary, the Abbé Imbert, has given an account of the methods there adopted, which is (as M. Degousée rather dryly remarks) more characterized by credulity than by discernment. It is quoted in Degousée's "Guide du Sondeur, ou Traité Théorique et Pratique des Sondages," as follows:—

"There exist in the province of Ou-Tong-Kiao many thousand wells, in a space of ten leagues long by five broad. Each well costs about one thousand and some hundred taëls (the taël is worth 6*s.* 3*d.*). These wells are from 1 500 to 1 800 feet deep, and of a diameter of from 5 to 6 inches.

"To bore them, they commence by placing in the earth a wooden tube of 3 to 4 inches diameter, surmounted by a stone edge pierced by an orifice of 5 to 6 inches. Then a trepan, weighing three or four hundred pounds, is allowed to play. A man mounted upon a scaffold depresses a lever which raises the trepan 2 feet high, and lets it fall by its own weight; the trepan is attached to the lever by a cord of ratan, to which a strip of wood is fixed; a man seated near the cord seizes this strip at each elevation of the lever, and gives it a half-turn, so that the trepan in falling may take a different direction. The workmen are changed every six hours, and the work goes on night and day. They are sometimes three years in boring these wells to the depth necessary to reach the springs they are intended to attain."

Almost all these wells give off considerable quantities of inflammable gas; there are some which yield, in fact, nothing else, and which are called "fire wells." It appears that the Chinese employ this gas as a combustible; doubtless it is nothing more than carburetted hydrogen, such as proceeds from coal mines in combustion. If M. Imbert

may be believed, some of these wells are not less than 3000 feet in depth.

In modern Europe the art of well-making was long confined to the simple operation of sinking circular shafts, until land-springs were met with; at least in the greater number of states. In the province of the Artois, however, the use of the boring-tool appears to have been generally known and practised from very early periods. The most ancient well in France, whose date can be authenticated, is one at Lillers, in the Artois, supposed to have been executed in 1126; and in that province the facilities for this description of work are such that a well is to be met with before the door of almost every peasant. In the north of Italy, at the very commencement of modern history, the arms of the town of Modena were two well-borers' augers; and a professor of medicine of that town published in 1691 a Treatise on Physics, in which many interesting notes are to be found upon the nature of different strata and water-courses, upon overflowing fountains, upon the manner of boring for these, and upon the excellence of the water they contain. Dominique Cassini, about the middle of the seventeenth century, endeavoured to introduce the system of boring more generally; and Belidor, in his work "La Science de l'Ingénieur," published in 1729, mentions the remarkable results which are often to be observed in these wells. He adds, evidently perceiving instinctively, so to speak, the theoretical conditions necessary to secure success in these operations:—"It were to be desired that many similar wells to those obtained by boring were formed in all kinds of places; but this does not appear probable, because certain circumstances in the disposition of the earth are necessary, which are not always to be met with."

In our own country, the first notice we find recorded of the application of boring is in the "Parentalia," in which Sir C. Wren is said to have adopted this precaution in order to ascertain the solidity of the foundation of St. Paul's in

parts where the original surface of the ground had been disturbed. Subsequently, towards the latter end of the last century, many wells were formed by this means, especially in the Wolds near Louth, and in the London basin near Tottenham; and the real principles regulating the flow of water in these wells were ascertained to a sufficient extent at least to allow of their execution being attempted with such probability of success as to justify their being commenced.

The execution of the Artesian well at Grenelle, near Paris, tended more than any other circumstance to direct public attention to this mode of obtaining water, not only on account of the remarkable success which crowned the efforts of the self-educated engineer, M. Mulot, in spite of all the difficulties and opposition he encountered in the long and anxious execution of the works, but also on account of the highly interesting discussions and the elaborate investigations to which it gave rise. MM. Arago and Walferdin followed the progress of the works in a spirit of enlightened philosophical inquiry which has led to the solution of many highly interesting laws of nature hitherto involved in mystery; and at the same time their confident predictions of the eventual success of the operation served to encourage M. Mulot, when too many others were disposed to throw doubt and ridicule on his efforts. The very remarkable confirmation of the *à priori* deductions of these philosophers affords also a remarkable illustration of the correctness of the received theory of the geological structure of the globe. But, singularly enough, the lessons afforded by this remarkable work have not been productive of all the scientific results we might have expected. Because water had been in this instance obtained in a position where there appeared no natural supply, it has been too frequently concluded that in all such cases the same results might be obtained, and that quantities of water were pent *up in* the ground, which only required to be tapped to

allow of its rising to the surface. But there are considerations affecting the supply, and the overflow from the water-bearing stratum, which so far modify the question as to render long and patient investigation necessary before such expensive borings, as these deep wells usually prove to be, should be commenced. Many disappointments have thus been incurred in the search for what after all could not reasonably have been expected; nor would it be possible to cite a more striking illustration than to refer to what has occurred at Southampton. We shall have occasion to allude more in detail to this work hereafter, when treating of the present state of the science of Artesian wells.

The economy of the application of boring, instead of carrying down a shaft of considerable dimensions, must be evident. A remarkable instance occurred at Mr. Vulliamy's, Norland House, where, after having dug as for an ordinary well to a depth of 236 feet, a boring was commenced, and a copper pipe 5¼ inches diameter inserted. After boring 24 feet, the spring was tapped, and the water rose 243 feet in one hour and twenty minutes. The sand also blew into the well 90 feet, thus choking to a great extent the flow of water: by clearing some of this away, the water overflowed the surface at the rate of forty-six gallons per minute. This occurred in the year 1794. It is evident that, in this example, had the advantage of boring been fully appreciated, and the geological situation of the place been accurately determined, much needless expense in well-sinking would have been saved.

In addition to its use in operations of well-work, boring is of service in a variety of ways; for mining purposes, railway works, examination of ground, such as in the case of a doubtful situation, testing morasses, and other such works. The reasonableness of its application is self-evident; a few pounds spent in boring may save hundreds which would be expended if the operation were to be neglected. The accounts that are sometimes given of the

quantities of earth swallowed up in filling a morass, so as to form a railway embankment, will occur to all as so much waste of material and labour. Generally, after a sufficient quantity of earth has disappeared to make the work assume a very serious character, a different method of proceeding is adopted. Now, by boring in the first instance, so as to ascertain the exact nature of the ground to be traversed, the right method of obviating the difficulty might be at once ascertained.

The application of boring to pile-driving has been attended with great success in France, and with a considerable diminution of the expense attending the ordinary process; but it is evident that it is only economically applicable when a certain degree of difficulty exists in driving by the monkey in the usual manner. In the "Guide du Sondeur," &c., before quoted, is an account of the boring operations carried on for fixing the posts of the electric telegraph from Paris to Versailles: 476 of these were fixed in their places in the course of a month; they averaged 3fr. 50c. each (2*s.* 11*d.*), some being executed in hard rock. As the ground was undisturbed, no necessity existed for masonry to consolidate the posts, which were let in to the depth of from 5 feet to 6 feet 6 inches. The passages for the tying-down bolts of the bridge of La Roche Bernard were also formed by boring. Indeed, the process is applicable either under water or on dry land, either in a vertical, horizontal, or inclined direction; and though its cheapness is most apparent when the hole is comparatively small, yet it is sometimes practised of a diameter of many feet, if the situation should not admit of excavation. Such a case as the above is frequently to be met with in well-work; thus in sinking iron cylinders through sand charged with water, the water must either be pumped out, or the sand bored through. The latter will always be chosen when the rush of water is great, or when the pumping *becomes expensive*. To enumerate every case in which

boring can be successfully applied would be useless; its capabilities for various purposes, whether for wells, for draining, mining, building, or purely scientific purposes, being now ascertained, every engineer can judge of the circumstances which should dictate its adoption.

There is, however, an application which is not sufficiently known in England, notwithstanding that an account of it has appeared in some of our professional journals: it is in the formation of absorbing wells, by means of which the waste waters of some branches of industry may be removed by their being carried down to an absorbent substratum, and some curious natural laws have been divulged by the experiments to which such works have given rise.

Thus, it has been proved that a well can absorb a quantity of water equal to what it yields. If, for instance, a boring yield 100 gallons per minute, and the water cease to ascend at 3 feet above the ground, by merely lengthening the tube 3 feet in addition above the permanent level of the water, 100 gallons may be continually poured in per minute without flowing over the orifice of the tube. If it be desired to make such a boring absorb say 500 gallons per minute, a pump able to raise that quantity is inserted in the well, and notice is taken of the depth to which it can lower the water-line. If we suppose it to be 15 feet, for instance, it will be sufficient to place a column of that length above the water-line, and the boring will absorb the quantity of 500 gallons. Should the water-line be below the surface of the ground, the absorption by this description of well may be indefinite.

Care must be taken to prevent any solid matters in suspension in the waters proposed to be absorbed from being carried into the boring, or they would rapidly choke it up. Precautions also require to be taken to prevent the contamination of neighbouring wells.

It appears upon a retrospective glance at the history of well-sinking, that its principles of execution are unchanged,

but that the practice is by no means so; and that both as regards their mode of construction and materials, considerable modifications have been introduced. As the art is now practised, wells may be divided into two classes,—the common, and the Artesian wells. The former are dug, and necessarily of considerable diameter, through the strata near the surface, to the spring itself, and are supplied by the filtrations of the immediate locality; the latter (named after the province of the Artois, where, as we have seen, they have been resorted to for many ages) are not dug, but bored through such retentive upper strata as may overlie a permeable stratum, the outcrop of which is at a sufficient height to produce a hydrostatic pressure upon the springs sufficient to make them rise in the tube of the bore.

In carrying on boring and well-work, a great deal of practical information applicable in other operations, and interesting in reference to the one going on, may be embodied by keeping a correct journal. The one here given is copied from a Model Journal by M. Degousée; and had such journals been always kept during the execution of the numerous wells lately sunk in the neighbourhood of London, by comparing them, much valuable geological information, and certain questions relative to the rise of water in wells, might have been ascertained with greater accuracy than hitherto. When a well is merely dug, of course the columns relating to boring-tools may be omitted, and when boring does take place, the list must be sufficiently extensive to embrace all the tools likely to be required. In the accompanying form the columns are filled up nearly at random, but sufficiently in detail to show how such a journal may be kept. Boring-rods have usually their lengths numbered on them, so that, if correctly screwed together in their proper order, the depth of the hole may be readily determined at all times.

JOURNAL OF BORING at being

a search for .

No. of Sorts or Samples of Ground.	1848. Days of		NATURE OF THE EARTH.	Number of Journeys of					Thickness Bored at the end of each Day.	Depth of Boring at the end of each Day.	Thickness of each of the Strata.	Distance of Water in Well to surface of Earth.	OBSERVATIONS. P.S. If possible, get level of surface above or under some fixed point well known.
	Rest.	Work.		Chisel.	Auger.	Shell.	Spring Rymer.	Latch or Recovering Tool.					
	December.												
1	..	16th	Surface soil	..	..	..	..	..	9′ 0″	9′ 0″	3′ 0″		Commencement of digging—diameter.
2	..	..	Clayey soil	..	..	..	..	..	..	..	2 0		
3	..	..	Fine sand. .	..	..	..	..	..	..	..	..		
		17th	Ditto	..	..	..	..	..	4 6	13 6	8 6		Finish of digging.
4	..	18th	Flint stones	6	..	..	6	..	2 0	15 6	..		Fixing guiding pipe for boring.
		19th	Ditto	6	..	..	6	..	3 0	18 6	..		
		20th	Ditto	8	..	..	7	..	..	..	5 0		
5	..	..	Marl	1	8	..	2	..	2 0	20 6	..		
	21st	..	.. ..	..	..	..	..	..	..	..	..	..	Holiday.
		22nd	Marl	2	2	..	..	..	..	..	2 0		
6	..	23rd	Grey marl and calcareous lamina	..	1	..	3	..	9 0	29 6	..		

CHAPTER II.

THEORY OF SPRINGS.

THERE are few branches of Natural History which have given rise to so much discussion as the theory of springs. The explanations which have been offered of the phenomena they present have been innumerable: some are partially true, and applicable in certain cases; some extremely absurd. It would be beyond the province of this work to relate the steps by which our knowledge upon this subject has assumed its present form, and it may therefore be sufficient to state that it is universally believed by the cosmogonists of the present day that the explanation of the flow of water from springs, whether deep-seated or superficial, is to be found in the fact that they are the lines of natural drainage; in other words, that they are supplied by the rain, hail, snow, and vapour precipitated upon the earth's surface, and part of which is absorbed thereby. A vast circulation of water is thus kept up. The rivers and streams, supplied by springs, in their turn contribute to supply the sea, which, together with the water generally, supplies the atmosphere by its evaporation, and thus completes the circuit. Though it has never been denied that land-springs, that is to say, springs found near the surface of the ground, are supplied by rain,—indeed, the fact speaks for itself, inasmuch as in dry weather they often cease to flow,—yet, that deep well-springs are supplied from the same source has been controverted; for, say the objectors, how is it that an increase of rain apparently makes no difference in the quantity of water, and, in like manner, drought appears not to affect them? A satisfactory answer to this will be found in the examination of the circumstances affecting such springs; it will be seen that they

are generally derived from reservoirs of porous matter interposed between impermeable strata, which reservoirs will naturally overflow at the points where the permeable strata, supposing them to assume a basin-like form, touch the surface of the ground. The waters which overflow at these points form rivulets and streams, and the effect of great rain or drought will be only to add to or diminish the quantity discharged by these natural channels; whilst little difference will be found in the height of the water-line in the main reservoir itself. The word *little* is used advisedly, because it has been shown by careful experiments that a slight difference does generally exist according to the different seasons of the year.

A very important point to be ascertained in the discussion of this branch of our inquiry was, whether sufficient rain falls to supply the rivers and springs supposed to be so supplied. From the mean of a variety of experiments, it has been found that the annual depth of rain which falls in England and Wales is about 31 inches, supposing the same collected on the surface of the ground, allowing none to soak in, and none to evaporate. In like manner, the depth of dew has been found to be 5 inches. The whole may therefore be assumed as 36 inches. Of this quantity, part is disposed of in the supply of rivulets, springs, &c., and part is again raised directly into the atmosphere by evaporation. Assuming that two-thirds go in this manner, we have still 12 inches deep for the supply of the rivers and springs, a quantity as follows:—The surface of England and Wales being 49 450 sq. miles, we have 5 280 ft. $\times$ 5 280 ft. $\times$ 49 450 sq. m. $=$ 1 378 586 880 000 square feet of surface; one foot in depth of water will change the above to cubic feet; so much for the supply. Now it has been calculated by Dr. Dalton that the Thames drains a tract of country of the area of 600 square miles, or about one-eighth of the area of the whole, so that if it be possible to calculate the water annually discharged into the sea by the Thames,

a rough approximation to the total expenditure of water can be arrived at. By some philosophers, who have paid attention to the subject, it has been calculated that the river Thames discharges daily 13 000 000 tons of water, which, multiplied by 35·84, the number of cubic feet in a ton, = 465 920 000 cubic feet; this again multiplied by 365, = 170 060 800 000 cubic feet, the quantity annually discharged into the sea by the Thames alone: eight times that quantity, according to the above assumption, or 1 360 486 400 000 cubic feet, will therefore equal the total annual expenditure of the rivers of England, an amount not quite equal to the supply by the rain and dew, the difference in favour of the supply being 1 378 586 880 000 − 1 360 486 400 000 = 18 100 480 000 cubic feet. From what has been said, there can be no doubt that in this country the rain and dews alone are quite sufficient to account for the flowing of all the springs; and analogy would lead us to suppose that in all countries similar causes would occasion like results. Thus, on the shores of the Mediterranean, it has been found that the evaporation from the sea is sufficient to yield about five times the quantity brought down by the water-courses. Mariotte, and subsequently M. Dausse, have also ascertained that the annual quantity carried down by the Seine is not more than one-third of that supplied by the atmosphere to the district which it drains: the remaining two-thirds of the rain must then either pass off by evaporation, or be absorbed by the vegetation, or serve to feed the under-ground springs.

The calculation of the yield of springs, when compared with the rain-fall of the district, will, in almost all cases, explain the origin of the former. The hasty conclusions to which unfortunately so many observers arrive, that the upper lands cannot yield the volume given forth by the springs, are only to be accounted for by the carelessness which so frequently marks this class of observations. For instance, in the singular documents lately issued by the

Board of Health to explain the scheme for bringing water from the green-sand formations upon the south and south-west of London, it is broadly asserted that the streams those formations give rise to are greater than they could be if they were only fed by the rain-fall of the district. Now, the volumes carried down by these streams were only ascertained by observations extending over a few months of one year, and consequently were far from giving a true average; and in addition to this, if the area of the country supplying the streams had been calculated, and the rain-fall taken into account, it would have been found that the effective volume did not exceed on the average of the whole year one-third of the quantity supplied by the atmosphere.

A partial examination of the strata of a district has led some persons to imagine that springs cannot be fed by rain falling on the earth's surface, because the latter, in the point immediately above the springs, is separated from them by clayey or rocky strata impervious to water. This objection is of no weight, for it does not follow that because the latter are supplied by absorption from the earth's surface, therefore the rain must sink into it vertically, any more than in the case of a common water-tank, where the water is conducted by pipes from an exposed surface to a reservoir. Now, if in the simile we substitute porous strata beneath impervious ones for the pipes, and suppose that the former are exposed to the rain at some distant points, an explanation of the whole matter is at once suggested. It will be found that the existence of numerous springs may be accounted for on this supposition, and that it also serves to explain the difference between land-springs and those called deep-seated.

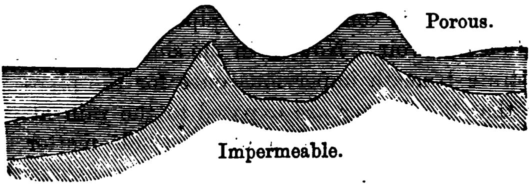
When the surface of a particular district consists of a loose permeable material lying upon a retentive substratum, the waters soaking through from above will descend until they meet with the obstacle it offers to their further descent. As such waters are not under any hydrostatic pressure,

they cannot rise above the ground, and, on the contrary, they rush into any artificial depression in the upholding bed: such sources of water are called land-springs.

Deep-seated springs, on the contrary, are those fulfilling more exactly the conditions we have supposed. Their supply is derived from the rain-fall upon the surface of the porous strata, situated at a high level, passing under an impermeable stratum, which soaks through them until it meets with a retentive substratum; and then, if it cannot find, or make, an outlet, the water follows the lowest levels of the permeable strata, according to the laws which regulate its flow above ground. If, under these circumstances, an opening be made through the overlying impermeable stratum, the water will rise to a height corresponding with the hydrostatical pressure upon it, excepting insomuch as it may be affected by the friction it meets with in its traject, or by the existence of any natural overflows. All Artesian wells are supplied by springs of this kind.

These general principles may be explained by reference to the Figures 1 to 6. In Fig. 1 a porous stratum is repre-

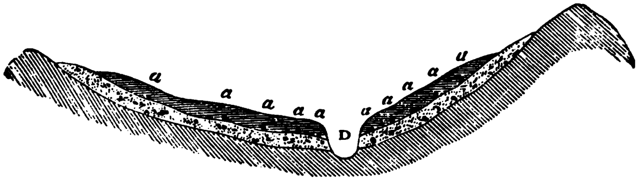
Fig. 1.



sented lying upon an impermeable stratum, and in this case a little reflection must show that the waters would collect at the lowest points of the depressions upon the top of the latter; and that if wells were sunk into this, the water from the upper stratum would flow into them. In Fig. 2, if we suppose the permeable stratum upon the sides of a hill to be covered by an impermeable stratum *a a a*, *and intersected by* a ravine or a water-course, it must be

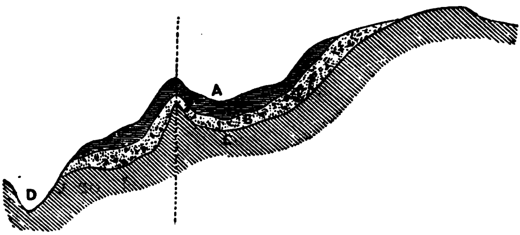
clear that the natural tendency of the waters falling upon the outcrop of the permeable stratum would be to descend to the ravine, unless a readier vent were offered at a higher

Fig. 2.



point. In Fig. 3, a portion of the waters would accumulate at C until they rose to a level above the projecting spur in the substratum: as soon as they passed this, they would begin to flow over towards D, and acting as in a syphon would effectually drain the intermediate porous stratum. In Fig. 4 an illustration is given of the phenomena presented

Fig. 3.



by the alternations of permeable and impermeable strata in which no ravine or water-course occurs to alter the normal conditions of the water-line. Fig. 5 is an illustration of the appearance often presented by the chalk formation covered by the drift gravel; in this case the bulk of the water would lodge in the depression below B.

In Fig. 6 is represented an ideal section of the London basin, showing the configuration of the strata, which serves to account for the supply of the numerous deep wells in the

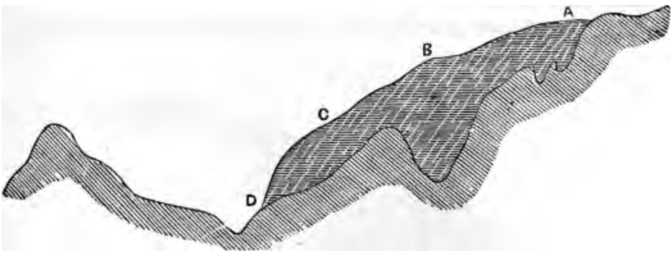
metropolis. All the water, falling upon the outcrop of the plastic clay and sand, passes under the impermeable blue clay, and if it be not afforded vent by wells sunk through

Fig. 4.

Impermeable.

the latter, it passes through the chalk, together with the waters falling upon the outcrop of the latter, until they

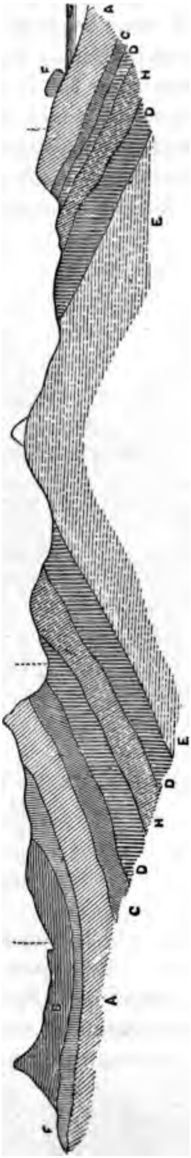
Fig. 5.



meet the retentive strata of the chalk marl, or until they rise to the surface by any natural vent.

The assumption that all and every spring on the globe is derived from surface drainage alone, is perhaps more than is justifiable in the present state of science; indeed some, by their brackish flavour, at once bespeak their direct oceanic origin. It is highly probable that some fresh-water springs do receive a supply from, and are modified by, the waters of the sea, derived thencefrom by capillary action. When the sea rests on porous matter, as chalk, no reason can be given why the water should not be absorbed by it,

Fig. 6.

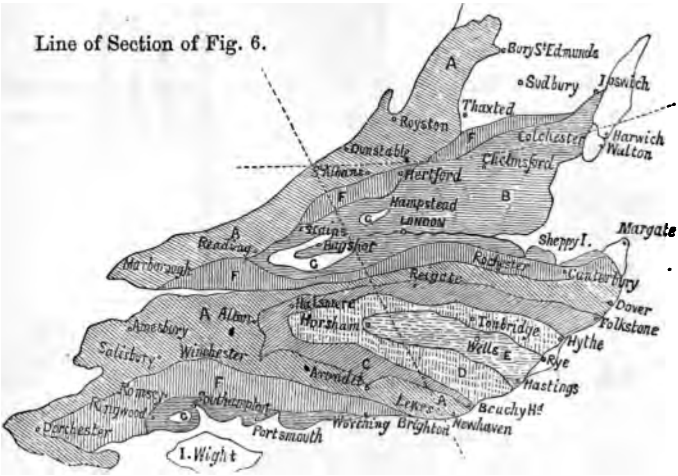


CROSS SECTION OF PART OF THE LONDON BASIN.—FROM F TO A, FIG. 7.

A Upper and Lower Chalk.
B London Clay.
C Chalk Marl and Fire-stone.
D Blue Marl.
E Iron-sand.
F Plastic Clay and Sand.
H Green-sand.

and affect to a certain extent the quantity and quality of drainage water which may be held in the same chalk reservoir; and this more especially when the water-level of the springs is at or even below the level of the sea. It is natural to suppose this action would be felt to the greatest extent near the sea itself—a supposition borne out by facts. For instance, a well wall lately sunk at Newhaven, in the chalk, by the London, Brighton, and South Coast Railway

Fig. 7.



Geological Map of the South-eastern Chalk Range of England.

A Chalk.
B London Clay.
C Chalk Marl and Green-sand.
D Weald Clay.
E Iron Sand.
F Plastic Clay.
G Bagshot Sands.

Company, yielded water which was seriously affected by the percolation of the sea. Reference to a geological map will show that those same chalk hills, as well as others abutting on the sea, are continued without interruption to *the main* chalk range on the western side of the London

basin; therefore, in a modified degree, the percolating action of the sea water must be felt in all parts of the basin at or near its level, and which are not cut off from this action by any uplifting of the strata under the chalk, as in Fig. 1. Hitherto no disturbance of the strata has been observed in this district which should lead us to suppose that any elevation of the lower strata exists by means of which the passage of the subterranean waters might be interfered with. The lower portions of the chalk are extremely dense, almost impervious, but not entirely, so that a possible though much choked communication between the sea and springs derived from the rain being thus established, we may expect to find in this water, in a diluted state, such salts as the sea abounds in, due allowance being made for various decompositions which these salts must necessarily undergo during the progress of their filtration.

A reference to Fig. 7, which is copied from part of Messrs. Conybeare and Phillips's geological map, shows the line of section represented in Fig. 6, as also the direct communication, though not in a straight line, between the chalk of Newhaven and the range on the western and north-western side of the basin.

But although some springs found near the sea-shore are unquestionably affected by infiltration from the latter, the theory that those occurring inland are supplied by rain, hail, dew, snow, &c., which originally are raised into the atmosphere by evaporation, is now allowed to be correct by all whose opinions are of any value. That until comparatively within a few years the discussion should have been unsettled, is not to be wondered at. Until Geology showed, by explaining the nature of the crust of the earth, the natural channel for subterranean currents, and accurate experiments had determined the immense extent of natural though unseen and unfelt evaporation, no decisive proof could be given to settle and determine the question.

Science has, however, now so far advanced that we can recognise the cause and the means whereby the alternate exhaustion and replenishment of the subterranean reservoirs are accomplished. Before entering more deeply into this subject, it will be necessary to form some conception of the order and arrangement of geological strata.

Strata of England and Wales in reference to their Springs.

The most superficial observer must be aware that the components of the surface of the earth vary greatly in different situations; in some places hard, crystalline, unstratified rocks make their appearance; whilst in others soft strata, evidently bearing the character of having been deposited in layers, will be found. This disposition a little closer examination will show not to be the result of an accidental confusion, but to follow from an order of superposition which it has been the province of Geology to ascertain. The purport of the present chapter is to lay before the reader the relation of these various substances composing the earth's crust, as connected with the subject of springs; and because the surface of the crust may be taken as an index of what may be expected underneath, it is desirable to give the order in which the various rocks and deposits are found. The reason that in all cases the same distance does not intervene between the lower rocks and the earth's surface is simply from the fact of the inclined, and not horizontal, position of the strata; and the alteration in the position of the strata may easily be traced to disturbances of a subsequent date to their deposition. Although the lower rocks outcrop and show themselves in many places on the earth's surface; and further, though some usually intervening rocks may be, and often are, missing between some of the upper and under beds of the series, yet, except under very unusual circumstances, none of the upper *ones* will underlie the deposit or rock which the order of

superposition usually places them above. Descending from what Geologists consider the latest formation, a section of the earth's crust may be represented as follows, a great many subdivisions being of course omitted.

Supra-cretaceous Formations.—Vegetable soil, gravel, crag sand, London clay, septaria, plastic clay, with beds of sand.

Cretaceous Group.—Chalk, chalk marl, upper green-sand, gault clay, lower green-sand, weald clay, iron sand.

Oolitic System, Upper Series.—Purbeck beds, Portland beds, calcareous sand, Kimmeridge clay.

Middle Series.—Coral rag, yellow sands, calcareous-siliceous grits, Oxford clay.

Lower Oolitic Series.—Cornbrash limestone, and forest marble, great oolite, or softish freestone, layers of clay, Stonesfield slate, fullers' earth, clay, sandy limestone.

Lias Formation—which consists of limestone beds, divided by layers of clay.

New Red Sandstone Group—consisting of variegated marls, sandstones, conglomerates, gypsum, rock salt, bone red or dark-coloured limestone, blue and blackish limestone, alternating with clay and marl, &c.

Magnesian Limestone.

Carboniferous Group.—Coal measures, sandstones, clays, shales, ironstone, millstone grit, mountain limestone.

Old Red Sandstone Formation.

Silurian System, comprising argillaceous limestones, sandstones, quartzose flints, flagstones, schist.

Cambrian System, or inferior stratified rocks of clay slate—mica slate, with dark-coloured limestones, sandstones, &c.

Plutonic Rocks, granite, syenite greenstone, hornblende, &c.

Water-bearing Qualities of these Strata.

It is not here intended to explain the properties of the various substances mentioned above, excepting so far as

they are connected with the consideration of springs in them. The vegetable soil comes first under review; such soil, if it rest on gravel or sand, will always be dry; but if it rest on clay, or any other retentive strata, will, unless well drained, be a complete swamp; on such a substratum rest those soils where the springs are within a few feet of the surface; should, however, gravel or sand succeed the surface soil, no water can be expected in it till a retentive seam of clay or other impermeable matter be met with. When sand, as at Hampstead, rests on London clay, very little difficulty is occasioned in getting a sufficient water supply from it; but such land-springs are, from their nature, very variable.

Gravel oftentimes rests on porous chalk, in many parts of Hertfordshire, for instance; in such positions no water can be expected to be met with in wells in the gravel, but they must be sunk to the saturated point of the chalk.

In the London clay formation there are few springs, and though by chance one may be met with, nobody would think of sinking a well in the London clay in full anticipation of getting water till that formation was passed through, and the beds of sand in the plastic clay formation were entered; in these there is a very copious supply.

The quantity of water held in the cretaceous group is enormous; the lower portion of the chalk itself, as far as the denseness of the material will allow, is fully saturated; all fissures in it are completely full, forming literally subterranean rivers. The strata directly under the chalk, consisting of retentive marl, will make it appear clear to all why the lower portions of this formation should contain so much water. The long lines of flint in chalk have been remarked on before, as favouring the percolation of water, and so has the fact that, in the London chalk basin, those circumstances exist that are required to insure *the success* of sinking Artesian wells. When wells are

sunk in the lower green-sand formation, water may be met with where clay seams occur; the water which supplies the deep-seated springs is held up by the weald clay under the sand. The water supplied by the iron sand is generally arrived at by sinking deep wells; but it is often impregnated with iron.

In the upper oolite system little water can be expected in the impermeable beds of Purbeck and Portland stone, except in fissures; under the Portland bed, however, is porous matter, and the water absorbed by it is retained by the underlying clay, thus rendering it accessible. In the middle oolitic series, the Oxford or clunch clay is the retentive medium, and wells must be sunk to the saturated portions of the overlying porous matter. In the Oxford clay itself are few springs. The lower oolitic formation has water retained by clay seams. In the cornbrash limestone and forest marble the wells are not very deep; under the great oolite, the fullers' earth clay retains the water. The limestone itself is porous to a certain extent, therefore wells must be sunk in it to its line of saturation, or its junction with the clay underneath.

The upper retentive beds of the lias formation supply water to the wells sunk in the lower oolite; and water may be met with in the upper portions of the lias formation for the same reason. Wells sunk in the lower portions of the lias formation have water retained in them by the upper marls of the new red sandstone group.

The alternations of sandstone and clay, rock salt, &c., in the new red sandstone, render water procurable in that group. The newspaper accounts of a shaft sunk in this formation at Gorton, by the Manchester and Salford Water-works Company, relate that the well is seventy yards deep; there are radiating galleries from the main shaft, and the quantity of water raised by the engine equals 2 000 000 of gallons per day.

In the magnesian limestone, fissures and holes contain-

ing water must be worked for. The great quantity of water in the carboniferous group is probably known to all, it being an element which, were it not for the large pumping engines constantly at work, would greatly impede the operations of the miner: the alternating porous and retentive matter in this formation fully accounts for the appearance of the water. The mountain limestone being porous, water can only be met with when beds of clay occur; the lower portions, however, of this formation are saturated, because impervious layers separate it from the porous beds of the old red sandstone. In this latter formation there is no lack of water, its components being partly porous, with retentive intervening layers.

Owing to the stratified character of the Silurian system, water may be met with in it; and in the lower Plutonic rocks, where they show themselves at the surface, the only chance of getting water is by sinking till a fissure fully charged with water is arrived at. Such an operation as this was carried on at Fort Regent, alluded to at p. 75; the rock in which that well is sunk is compact syenite, intersected with vertical fissures.

With reference to the geological strata that occur in other parts of the world, the general order, the series, and the strata themselves generally correspond to those in England and Wales, although special or local names may be used in their nomenclature. Some exceptional strata occur that are unrepresented in England, and any series or stratum may be entirely absent. The following is the usual general classification:—

Kainozoic.— Postpliocene, Pliocene (2 sub-divisions), Miocene, Eocene (3 sub-divisions).

Mesozoic.—Upper Cretaceous, Lower Cretaceous, Oolitic (3 sub-divisions), Liassic, Triassic.

Palæozoic.—Permian, Carboniferous, Devonian, Silurian (4 sub-divisions), Cambrian, Laurentian.

CHAPTER III.

SPRINGS AND SUBTERRANEAN WATERS.

Before illustrating more particularly the various circumstances affecting the supply of water to springs, some of the most remarkable may be mentioned; and among them, the hot springs of Iceland claim attention. One of these, called the Great Geyser, is thus described:—The fountain is situated in a circular mound of matter, deposited by the water itself during the lapse of ages. In the centre of this basin a perpendicular inlet, about 10 feet diameter, descends into the earth, and communicates with the supply. The basin is usually covered, to a depth of about 4 feet, with clear hot water, which flows away by two passages situated in the sides of the basin. At the time of eruption, which occurs at intervals, the first signal is a rumbling noise and low report; after which a few jets of water are thrown up; the jets become higher, and the noise becomes louder, till at last a defined jet, 50 to 100 feet high, is formed, and of a diameter equal to the main inlet: the eruptions seldom last longer than a few minutes, and they occur at irregular intervals, seldom exceeding many hours. The water has the property of incrusting with mineral matter objects over which it flows, also covering the parts round about it with siliceous incrustations.

The fountains of Vaucluse and Nîmes are equally remarkable on account of their volume. The former, directly after leaving the ground, is known as the river Sorgue, and is of such immense volume as to yield 444 tons of water per minute in the driest seasons, and 1 330 tons in very wet weather. The latter is of smaller volume, but interesting on account of its intimate connection with the rain-fall; thus, in dry weather, it hardly yields more than one ton

and a half per minute; if, however, any rain fall on the north-west of the town, even at a distance of four or five miles, the volume almost instantly increases to ten tons. The river Loiret is also supplied in precisely the same manner as the Sorgue: it rises in a large basin with considerable force, and flows away a river navigable for barges of two or three hundred tons burden.

Spallanzani mentions a spring of fresh water rising in the sea in the Gulf of Spezzia at a distance of sixty yards from the shore. It forms a dome upon the surface of the sea about 30 yards diameter, with an elevation of about 16 inches in the centre, and is composed of a number of vertical jets, which are very perceptible when the sea is calm. Many other such sources of fresh water have been recorded; for instance, in the Bay of Xagna, off the Cape San Martino, in the principality of Monaco, and in the Indian Ocean, about 100 miles from the shore.

The account of the two following springs is copied into Rees's Cyclopædia from the Philosophical Transactions:—

"In the diocese of Paderborn, Westphalia, there is a spring which disappears twice in twenty-four hours, and always returns at the end of six hours with a great noise, and with so much force as to turn three mills not far from its source. It is called the Bolder Horn, or Boisterous Spring." Again, "At Broseley, near Wenlock, in Shropshire, there is a famous boiling well, which was discovered in June, 1711, by an uncommon noise in the night, so great that it awakened several people, who, being desirous to find what it was owing to, at length found a boggy place under a little hill, not far from the Severn, and perceiving a great shaking of the earth and a little boiling up of the water through the grass, they took a spade, and digging up some part of the earth, the water flew to a great height, and was set on fire by a candle. This water was for some time afterwards constantly found to take fire, and burn *like spirit of wine*; and after it was set on fire, it would

boil the water in a vessel sooner than any artificial fire, and yet the spring itself was as cold as any whatever. This well was lost for many years, and not recovered till May, 1746, when, by a rumbling noise under-ground like to that the former well made, it was hit upon again, though in a lower situation and thirty yards nearer the river: the well is four or five feet deep, and six or seven wide; within that is another less hole of like depth, dug in the clay, at the bottom of which is placed a cylindric earthen vessel of four or five inches diameter at the mouth, having the bottom taken off, and the sides well fixed in the clay rammed close about it. Within the pot is a brown water, thick as puddle, continually forced up by a violent motion, beyond that of boiling water, and a rumbling hollow noise, rising and falling by fits five or six inches; it may be fired by a candle at a quarter of a yard distance, and it darts and flashes in a violent manner about half a yard high; it has been left burning forty-eight hours without any sensible diminution."

It is needless to remark that the above phenomenon is owing merely to the presence of a portion of gas brought to the surface in combination with the water.

Laws of Springs and Subterranean Waters.

For ages many absurd fables were believed with respect to the best methods of discovering springs, and even at present the divining-rod has not lost its partisans. There are still few parts of the world in which the professional water-finder may not be met with. Such persons exist in England, France, America, India, and in Oriental countries. Sometimes they are sincere, and to a certain extent capable, but more frequently they either deceive both themselves and the public, or are mere quacks imposing on credulity. It is, however, undoubted that some persons are keenly sensitive to change of humidity, and hence possess special powers, apart from that due to knowledge of locality. If, however, we pass over such

methods, there are some indications which may lead to the discovery of springs in cases where nothing would appear, to those unaccustomed to observations of natural phenomena, to induce a belief in their existence. The following are some of the most simple.

In the early part of the year, if the grass assume a brighter colour in one particular part of a field than in the remainder, or, when the latter is ploughed, if a part be darker than the rest, it may be suspected that water will be found beneath it.

In summer, the gnats hover in a column, and remain always at a certain height above the ground, over the spots where springs are concealed.

In all seasons of the year, more dense vapours arise from those portions of the surface which, owing to the existence of subterranean springs, are more damp, especially in the morning or the evening. It is for this reason that the well-sinkers of Northern Italy go in the morning to the places near which it is desired to sink a well; they lie down upon the ground, and look towards the sun, to endeavour to discover the places in the neighbourhood from which denser vapours may arise than from the rest of the field.

The springs to which these rules apply are such only as are near the surface; when the source is lower, they are rarely sufficient, and the only safe guide is a boring; but to execute such operations with any chance of success, a certain knowledge of elementary Geology is absolutely necessary.

Provided that the sources do not descend to any very great depth, the principle *that subterranean waters follow precisely similar laws to those upon the surface* holds good; but when they are very deep-seated, many disturbing causes, to be noticed hereafter, modify their action. If, in a valley formed in a diluvial or alluvial deposit lying upon a more retentive stratum, the two sides are of the same

height, the water must be sought in the middle; and if, on the contrary, one side be steeper than the other, the stream would pass near the steeper side; in both cases supposing that the materials of the upper stratum are equally permeable throughout, and that the depression of the lower stratum presents a tolerably regular basin-like depression. Springs are not often to be met with at the head of valleys, but they are much more frequently to be found at the intersection of the secondary valleys with the principal one; and the most favourable point for finding water is usually that which is the furthest from the intersection of these valleys, and in the lower parts of the plain succeeding them, at precisely those positions where there is the least water upon the surface.

When the transverse valleys, giving forth streams to a river in the bottom of a longitudinal valley, are nearly at right angles to the direction of the latter, the quantity of water they yield is much less than when they form an angle with it. This law holds good equally with subterranean and with surface waters, and it may therefore be laid down as a maxim that the most favourable point for seeking a supply by a well would be at the mouth of long transverse valleys inclined to the principal one.

When, as we have before supposed, and as in fact occurs in the London basin, permeable strata are exposed over a great surface of country, and pass under more retentive ones, whilst at the same time they themselves lie upon others of that nature, by the usual laws of hydrodynamics the water falling upon their outcrop will descend to the lowest level of the basin, nor will it begin to overflow until the whole of the depressed portion is saturated. A boring through the upper stratum will then become filled by the water from below to a point corresponding with the altitude at which the waters are maintained in the basin by the natural overflows. These abstract principles, however, are only applicable when the basin is not disturbed; and it is

particularly to be noticed that the existence of any large fissure in the external ridge of the basin, giving passage to a water-course, will be found to regulate the height of the waters to a very considerable distance from it on either side. If, however, any extensive fault exist in the bottom of the basin, by means of which the permeable stratum should be placed in communication with any other of a similar character, the waters will necessarily flow into the latter. The success of a boring for an Artesian well depends, in fact, so far as the mere retention of the waters is concerned, upon the perfection of the basin formed by the upholding stratum; and, so far as the height of the water-line is concerned, upon the level of the streams flowing from the water-bearing stratum.

The existence of causes susceptible of modifying to so great an extent the success of an operation of this kind is not sufficiently known, either to the public in general, or to those who by their professional position ought to be better informed. Unfortunately, the *science* of well-boring does not exist in England, and the execution of this description of work is usually left to mere practical men. The consequence has been, that several wells have been commenced, have given rise to great outlay, and, after disappointing the hopes of all concerned, have been abandoned. It is true that the knowledge of the geological disturbances of strata, often hidden entirely, must be always to a great extent hypothetical, but there are indications sufficiently clear to lead any practised Geologist to say beforehand whether any disturbance or fault exist likely to compromise the work proposed to be executed. With the most elaborate investigation and the most extensive knowledge, there is always a degree of chance about the first well bored for the purpose of reaching deep springs in any district. It is not therefore surprising that the majority of the attempts hitherto made in our country should have been failures.

The remarkable success of the Artesian well of Grenelle appears to have inspired a fever for undertaking others of a similar nature; and it is even now almost universally considered that if a boring be carried through the chalk into the green-sand, the water will rise above the ground. But in the first place it is to be observed that in the Paris basin the supply for the wells of Elbœuf and of Grenelle is derived from the lower green-sand which lies upon the retentive strata of the Wealden, and that it enters the sand at a point very much above the position of the wells, as also that the last considerable streams from the green-sand are at a much higher level than the same position. Similar borings near Calais have signally failed; for the subcretaceous formations there repose upon the carboniferous strata, without the interposition of the oolites, the lias, or any of the intermediate series. In this case the only chance of success would have been in finding some depression in the older formations filled with water, but of course it could never rise to any useful height.

The well at Southampton has afforded also some very important lessons with respect to the disturbances or modifications likely to be met with in the prosecution of such works. It was commenced at a point about a mile and a half from the sea, and 140 feet above the level of the high tides. As too frequently happens, no survey of the entering ground of the green-sand formations was made before commencing it; nor were the disturbances of the chalk strata, the only ones exposed in a manner able to furnish any valuable indications, taken into account. Now it happens that the green-sand ridge is disrupted in several places on the edge of the basin supposed to hold the waters from which the well was expected to be supplied, and important rivers flow away from it at those places, at levels little above the ground at the well. Should a water-bearing stratum exist, therefore, the water can rise very little above the ground, even supposing that all the other

necessary conditions be fulfilled. But the whole of this part of the country has been disturbed in a very remarkable manner. A very strongly marked fault exists in the chalk near Winchester, and continues to the sea-shore near Portsmouth. The sea has formed two large breaches in the containing basin of the green-sand on the east and west of the Isle of Wight. At the back of the island the marks of geological disturbance are even more evident than upon the north of Southampton; the strata are contorted, and even tilted up in a vertical direction. The same facts occur also more to the south-west, near the Isle of Purbeck, so that there appears little reason to believe that the basin is continuous; and at any rate the sea is in direct communication with the green-sand formations: if, therefore, it do not affect the quality of the water contained in the green-sand, it must regulate the water-line, and cause it to take a regular inclination corresponding nearly with a line drawn from the last great inland overflow to the sea water-level. But it is found that the water obtained from the chalk itself in the present state of the work is strongly affected by the infiltration through the body of the rock from the sea. If this be the case with a substance comparatively so dense as the chalk, the probability that the same effect will take place with the more pervious materials of the subcretaceous rocks amounts almost to a certainty.

Again, in all cases where wells have been sunk to a great distance from the surface, it is known that at a certain point the temperature becomes constant, and that beyond this it increases according to a law susceptible of modification by local circumstances. Mr. Paterson (Edin. New Phil. Mag., 1839) gives the mean rate of increase in Scotland as being about 1° Fahrenheit for about 48 feet of descent. M. Walferdin found in Paris the increase was at the rate of 1·8 Fahrenheit for every 102 feet 10½ inches (or 1 centigrade for $30^{m}·87$). M. de Girardin found

at Rouen that it was about 1·8 for 67 feet 4 inches in one case nd 1·8 for 100 feet descent in another; whilst the more accurate experiments upon the Artesian well of Grenelle show that the increase there is with remarkable regularity 1·8 Fahrenheit for 106 feet descent below the point of constant temperature, which is about 93 feet 6 inches from the surface of the ground at the Observatory of Paris, and marks a little more than 53° Fahrenheit. This would give an increase of temperature of about 1° Fahrenheit to 59 feet descent. This important law does not appear to have been much attended to in England, or certainly, as in the case of Southampton, the notion of obtaining the whole supply of the town from a deep-seated Artesian well would never have been entertained. The boring has been carried to a depth of 1 320 feet nearly, still in the chalk, so that even did a supply of soft water exist at that depth, it would have a temperature of nearly 75° Fahrenheit. From these combined reasons, the inhabitants of Southampton have been induced to abandon the boring on their Common,—unfortunately not before they had spent a very large sum of money upon a work which, if a survey of the district had been made by a competent person, would never have been commenced.

The secondary rocks frequently give off powerful springs without any apparent indication of the existence of the interchange of strata we have hitherto considered. Well-known instances of this occur in the springs from the chalk near the head of the New River at Chadwell and Amwell, at Otterbourne, near Southampton, and at several other points in the valleys of the great chalk mass of the south-west of England. It will, however, always be found that these springs occur in valleys much below the general level of the formation, and their overflow usually corresponds with the existence of some fissure above a harder and more retentive bed than the mass of the chalk. The same remark holds good with the oolites and the lias; but,

in addition to the inequality of texture in the bulk of the formation, these particular ones are more likely to throw off springs, owing to the existence of numerous intercalated beds of stiff clay. It rarely happens, however, that these retentive strata can be traced with certainty over a sufficient area to warrant the commencement of any expensive works upon them.

The primary rocks are even more unfavourable than the older secondary rocks for the ascertaining by any abstract rules the existence of springs. There stratification is rarely persistent over a great extent of country, and the permeable materials, forming as it were filters, so seldom exist, as to make the occurrence of deep-seated springs very rare. Water may permeate these rocks in their numerous fissures, but necessarily it is impossible to predicate what may be their direction, or what conditions of hydrostatical pressure may exist. It may be asserted, indeed, that no abstract law prevails regulating the flow of water in these strata, and consequently that no boring should be attempted in them until the last extremity, because its success must be a mere matter of chance. Further details upon this subject have been already given in Chapter II.

If many Artesian wells be sunk in the same stratum and be supplied by the same deep-seated springs, it becomes necessary to ascertain the rate of inclination of the water-line before any exact conclusions can be arrived at with respect to the definite results of a new boring. Of course, as the outcrop of the water-bearing stratum is only exposed over a certain area, the quantity it can yield must be limited; and for the same reason, if much water be withdrawn at a high level, the lower wells must suffer. That this is a real danger is proved by the state of the wells near London, supplied by the water filtering through the plastic clay. So many have been sunk, that very few of those which formerly overflowed the surface now rise to

within some distance of it, and the volume yielded is also considerably reduced. The wells in the chalk near London are also producing the same result, and the water-line is annually lowering. The Rev. J. C. Clutterbuck, of Watford, who has paid great attention to this subject, has found that the water-line of the chalk near London has a general inclination of 13 feet in a mile upon a line drawn from Watford to the Thames, until we approach Kilburn, where a depression takes place, owing to the pumping around London, as he supposes. North of Watford, the rate of inclination was found to be as much as 200 feet in fourteen miles, but it was affected by the degree of saturation of the lower strata. In the Hampshire chalk basin, the rate of inclination has been stated to be 13 feet in a mile; so that numerous local circumstances require to be taken into account before any decided opinion can be arrived at upon this point, and equally numerous observations are requisite to furnish the elements of any philosophical reasoning upon the subject: in the last-named geological basin, however, it is more easy to observe the phenomena attending the inclination of the water-line, because no pumping takes place at the lower end to interfere with its normal condition. We find that from the well at East Oakley (about sixteen miles from Southampton) the water-level, which is there about 302 feet above the Ordnance datum, lowers to about 100 feet at the well upon the Southampton Common. But the rate at which the water-line lowers is far from being regular; it is more rapid near the summit, more gradual as we approach the sea, and may be represented by a parabolic curve. There are local irregularities occasioned by the outburst of considerable springs, due probably to some dislocation of the strata; but the general inclination prevails with tolerable regularity.

Stated generally, the laws regulating the height to which water will rise in an Artesian well are as follows: it will

rise to the height of the point of supply, with a diminution caused—1st, by the loss of some portion of the water through fissures; 2ndly, by the friction it meets with in traversing the water-bearing stratum; but it must always be borne in mind that the existence of a large natural overflow will lower the general water-line to its own level.

The phenomena of intermittent springs may be explained upon the principle that under-ground waters follow the same law as those flowing upon the surface: if a natural syphon be supposed to communicate with some subterranean basin, and it discharge the water more rapidly than the supply arrive, the reservoir will from time to time be so lowered that the syphon will cease to act. Under these circumstances the flow will be interrupted until the water rises again in the syphon to a height sufficient to cause a recommencement of its action. This alternation of flow will happen at intervals corresponding with the proportion between the capacity of the supply and of the discharging syphon. And finally we may state that no apparent anomalies exist which may not be explained by the geological and hydrodynamical considerations above detailed.

CHAPTER IV.

PRACTICE OF WELL-SINKING.

THE practice of well-sinking may be properly classed under two divisions, digging or excavating being one, and steining or lining with brickwork or stone the other; in the case of hard chalk or rock, the latter operation is dispensed with, the work being confined solely to excavating, —a lining of brickwork being quite unnecessary for the stability of the work. Wells are usually of a circular form, and those which are merely picked in the solid strata lack *the regularity of* the nearly perfect cylinder of brickwork:

such wells, however, generally require steining to some depth from the surface of the ground, owing to the looseness of the surface soil; this is exemplified in many parts of Hertfordshire and elsewhere, where a gravelly surface soil overlies the chalk. The mere excavation of a well requires but little skill, though at times it is a matter of great labour, requiring in hard rock blasting; the plumb-bob and a rod marked with the diameter of the hole being sufficient to insure accuracy. Buckets, a windlass, and ropes are required to remove the products of the excavation. These tools are sufficiently known to allow us to dispense with any description or illustration of them. Where the well is sunk through stiff clay, as, for instance, that in the London basin, steining of half-brick thick, or four inches and a half, is required for small wells, and of nine-inch work for wells of large diameter. Great improvements have latterly been made in the method of executing, and also in the stability of this description of brickwork, owing to the use of Roman and other descriptions of cement entirely superseding wedges of slate, bond timber, and common mortar: the two latter are especially injurious, as the timber will decay, and the lime in the mortar, unless it be a blue lias or other equally hydraulic lime, will dissolve out into the water contained in the well, rendering the same very hard; besides, as will be seen when describing the manner of steining, the slow setting of the mortar is a bar to its general use. Loose wet sand, or loam, test the skill of the well-diggers: in such cases, however, it may become necessary to puddle behind the brickwork,* and care must be taken that the upper steining should not

* The use of puddle for any purpose of hydraulic engineering is now nearly out of date; and it would be abandoned altogether, did our Engineers or Architects insist upon the preparation of concrete in a scientific manner. Unfortunately this is not the case, and the real direction of this important branch of construction is left entirely to the care of perhaps the most uneducated class of workmen.

slip whilst this work is being executed. Again, in passing through land-springs, they must be carefully walled out, by executing the brickwork entirely in cement—an operation which can only be accomplished when the quantity of water entering from the spring is limited: where the rush is enormous, as in sinking through the main sand-springs of the plastic clay formation, the water must be dammed out, by substituting for brickwork cylinders of iron, which may be either cast or wrought: the latter are the more modern, and have been applied in some large wells; the former are the more convenient for handling, being bolted together in segments, or in divisions. When the sinking such cylinders is necessary, digging will most probably be precluded altogether, and boring alone will be admissible, the cylinders sinking as the sand is bored out: when they have been sunk to a sufficient depth in the solid clay beneath, digging and steining may go on as before. If it be determined to bore, near London, into the chalk, the boring should commence before the sand-spring is entered, the expense of large cylinders being thereby saved, as their place would be taken by the small bore pipe; and as the water from the chalk will generally rise higher than the level of the sand-spring itself, no advantage is gained commensurate with the increased outlay by sinking large cylinders. The position of the sand-spring can be determined by boring in advance of the well itself, while the latter is being sunk through the plastic clay: by driving a bore-hole very small, and thus feeling the way, no danger of a surprise may then be anticipated.

Steining is executed in a variety of ways, as regards its manner of application, its thickness, and its bond. The bricks used should be hard, square, and well burnt; if the cost will allow, malm paviours should be used, and if stocks are employed they should be the very best. As the work is for the most part laid dry, unless the bricks run of one *uniform thickness*, a great waste of time and trouble will

unnecessarily take place during the steining: again, as the bricks are laid so as only to touch each other at the edges, a soft crumbling brick would manifestly be useless. The old method of executing the steining was by building on a curb of wood shod with iron. The earth being removed

Fig. 8.

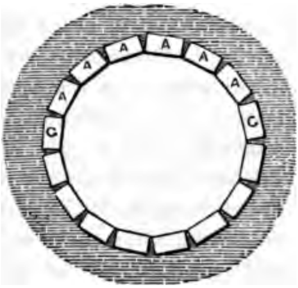
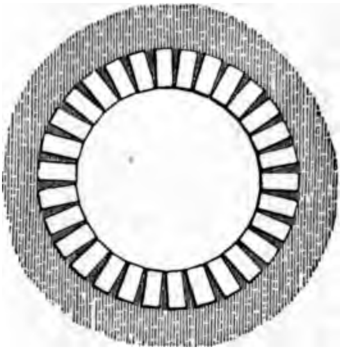


Fig. 9.

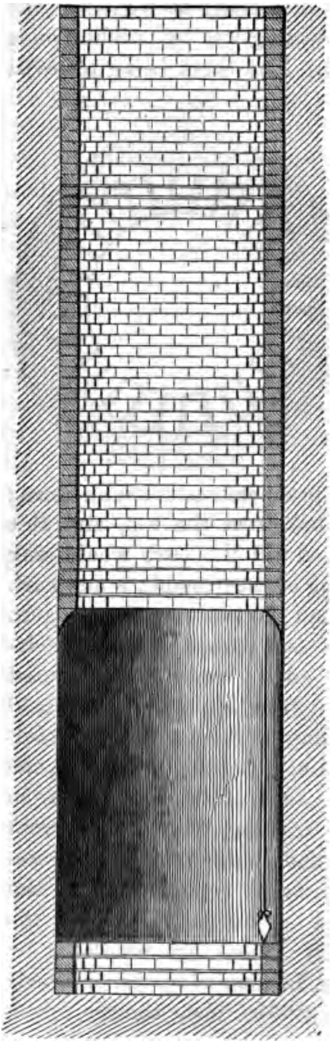


from the bottom, the curb and its superstructure sunk down; the brickwork was then added from the top, and this method of proceeding continued till the curb would sink no longer, owing to the swelling of the ground; a new curb and new excavation smaller than the last were then begun.

This method is now seldom used except in peculiar circumstances, all pricks being added under the executed steining, the latter being kept from slipping by artificial means when the natural swelling of the ground is insufficient; this circumstance is unlikely to take place when the bricks are worked close to the sides of the excavation, in clayey soils especially; the friction acting to prevent slipping is most enormous. The steining is usually executed partly in dry and partly in cemented work, the latter occurring as rings laid at intervals between the portions of the work laid dry: these are regulated by the nature of the ground; in London clay, the intervals generally vary from five to twelve feet, though some-

times the work requires to be laid for some distance entirely in cement. The rings are usually three courses thick, averaging about nine inches in height; the bricks are laid flat, as in Fig. 8, the courses alternately breaking joint: it is often desirable to insert cement or small wedges in the open spaces at the back of the touching edges of the bricks. The thickness of the steining itself depends on the diameter of the well and the nature of the ground to be passed through; some use nine-inch work laid dry, and radiating as in Fig. 9; this is evidently not so strong as four-and-a-half-inch work laid in cement, or even backed with the same in the manner described above; therefore, if nine-inch work be ever used, it should be laid in cement, as being in a situation where four-and-a-half-inch work in cement will not suffice. In commencing an excavation from one cement ring to another, the hole is dug as far as is safe or practicable; the nature

Fig. 10.



of the ground will determine this; a line is then plumbed (see Fig. 10, which represents a section of the steining of a well) from the brickwork above, which will give the position of the face of the brickwork in the lower ring; the cement is usually gauged with half sand, as in works above ground. Too quick setting a cement is not desirable, as it partially sets in being conveyed down the well to the workmen; Roman, blue lias, Portland, or any approved water cement, may be used for the purpose. In many cases, even where the work does not absolutely require it, the steining is done entirely in cement, a practice which makes excellent work, but which is attended with a further disadvantage than the extra cost of execution, because it occasions much trouble and loss of time in fixing the permanent pumps, and temporary ones also, if any are used.

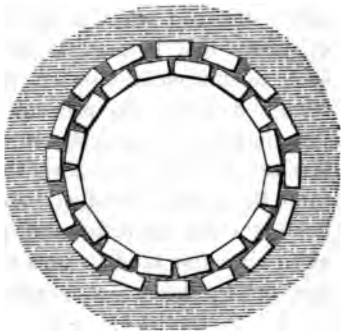
In sandy soils, should the well not be deep, the old plan of working on a curb may be adopted, but in deep wells that is inadmissible; here the steining should be set entirely in cement, and, to prevent slipping, the work should be laid in quarters, care being taken to well hang up the steining on the completion of the work by the insertion of an iron curb, secured in its place by tie-rods, which are carried up the shaft and bolted to cross timbers or another curb fixed into the brickwork. In some wells that have been executed in sandy soil, cast-iron curbs have been inserted at intervals, each curb slung to the one above it by tie-rods; the gravel or sand can then be excavated under the curb as the clay can under the brickwork rings set in cement; the curbs, in fact, bearing the same relation to the cemented brickwork, in the case of sandy soils, as the cemented rings do to the dry brickwork in clayey ground. The method of bond or laying the bricks remains to be considered: Fig. 8 shows this. The bricks, though they do not touch exactly at the edges, for practically that is impossible, yet are set in but a mere trifle, and the harder the description of brick the more

nearly may the edges abut; the swelling of the ground will soon fill up the spaces at the back of the edges when the bricks are laid dry: this method induces fewer joints than if the work were laid as in the manner usually adopted for half-brick arches above-ground, and for other reasons is more fit for this purpose. The ground behind them prevents any displacement of the bricks, for, the tendency of the pressure being to twist them, a compression of the ground must necessarily take place before movement can occur; thus the bricks, A, A, A, &c., in the figure, before they can be moved nearer to the centre of the well, or alter their position, must force outwards one or other of their two neighbours, G, G; these cannot evidently be so moved without compressing the solid ground behind: here, again, we see the advantage of working as close as possible to such ground, and if at any time, owing to a stone or otherwise, the excavation be not perfectly round, care should be taken to puddle with solid clay behind the steining, to prevent displacement, by thus forming a sufficient abutment.

The work when 9 inches thick is laid either radiating, as in Fig. 9, or in separate 4½-inch rings, Fig. 11; the latter plan is usually adopted, and may be considered the best, for the following reason, it being understood that the work in both cases is laid in cement. Considering the strength as that of a compound of bricks and cement in Fig. 11, fracture of the cement must take place before any failure, while in Fig. 9 a slipping of the bricks away from the cement might occur; and again, in executing the work it might be considered advisable—indeed, it generally is—to execute the back steining first, for a certain distance, and afterwards to complete the inner. Even work, not wavy, but strictly vertical, constitutes good steining, and looking upwards from the bottom of a well will at once detect if the work be true or not, the eye in such case being placed close to the *steining*.

Well-diggers, after attaining a certain depth, find the confined air very unpleasant and noxious. The carbonic acid from the breath, being specifically heavier than common air, soon stagnates at the bottom of the excavation: lime-water is sometimes recommended, as this will absorb the carbonic acid; it is, however, an awkward and unworkmanlike expedient. A pair of bellows or a fanblast should be used in such cases, and the air conveyed down the well in pipes; thin zinc ones answer the purpose very well; they are about 2 inches diameter. The depth of hole at which an artificial supply of air is desirable will depend on the diameter of the well and the position of the aperture. If it be open to the air, with no temporary shed or other erection over it, a supply may not be required, with a 4-feet excavation, till about 130 feet from the surface. In this question, however, the extreme limits should not be sought for, as the sooner a plentiful supply is given the better, the workmen getting on more comfortably to themselves, and also much more rapidly.

Fig. 11.



In the construction of iron steining the wrought-iron cylinders are riveted with internal ribs of angle or T-iron, so as to be flush on the outside, the rivets being countersunk to attain this end; lowering rings are also riveted inside them, for convenience in fixing. Cast-iron cylinders being much thicker, and therefore heavier, will sink into the hole with less driving; they are cast in about 5-feet lengths, and are joined together with bolts and internal flanges. In sinking cylinders, their vertical position must be insured by letting them travel or slide between four

battens, fixed as guides, and secured to the brickwork. When iron cylinders are used, it is generally necessary to secure up the lower part of the brickwork, as the sand and water will give it no support; an elm or iron curb is therefore used for the purpose, which is attached by iron rods to wood beams let across the well, or iron curbs inserted some distance up the shaft. The space between the cylinders and brickwork should also be well concreted, so as to shut out the water, which would otherwise rise up from the sand. To prevent land-springs or drains from percolating into a well, it is advisable to execute the first ten or twelve feet from the surface in 9-inch work, the same being well puddled behind. When the surface soil itself is close upon the stiff clay, this may be neglected; and, when the land-springs are very strong, they must be shut out by the use of cylinders, as previously described.

CHAPTER V.

BORING.

THOUGH boring practically requires skill and care, yet in principle it is extremely simple. The operation consists, as its name would imply, in working a hole, in this case made in the crust of the earth, of a diameter varying according to circumstances, and in a vertical direction generally; not so always, however, for certain requirements may demand that it should be oblique. Many systems have been and now are practised in carrying on this kind of work; and though in England but one is usually followed,—of many modifications, it is true,—yet it would be well to mention one or two other plans. The simplest is that practised in various parts of the Continent, and called the Chinese system; here all rods connected to *the boring-tool* in the ordinary plan are dispensed with,

the borer being suspended by a rope, which, when the tool is worked vertically up and down, imparts by its torsion a sufficient circular motion to the tool. In this case the tool and the rope are surrounded by an iron cylinder, and the products of the excavation become collected in the circular space between the tool and the cylinder, by which means they may be brought up to the surface of the ground. With so simple a machine, different tools, of course, being used for various strata, it may be asked, why has this plan not superseded all others? Now, where simplicity can be gained without corresponding disadvantage, it is well to employ it; but where a manifest inferiority exists, to choose simplicity in opposition to complexity, for its own sake alone, is absurd. To this plan one serious drawback occurs, which is, that the bore-hole is apt to become crooked, so that a great difficulty, if not impossibility, would take place in sinking the pipes necessary for protecting the hole. That this fault could be rectified there can be little doubt; but until this is done, the system of boring by impact alone, assisted by the twisting action of the rope, will never become very general. In rocky strata, or in places where the straightness of the hole is of little moment, this method may be applied.

The ordinary plan is to attach the borer, which differs according to the nature of the work to be done, to iron rods screwed together in lengths of from ten to twenty feet; a circular motion being given to the borer by the workman above, assisted when required by a vertical jumping motion, causes the boring-tool to work for itself a hole in the ground. It is evident that by this plan a great loss of time is entailed, for the tool, when it becomes full of the products of the boring, must be drawn up to the boring stage to be emptied of its contents, and to effect this the rods must be unscrewed. This unscrewing and screwing, pulling up and letting down, is an operation entailing a

great loss of time, which it would be important to supersede. An apparatus has been proposed to accomplish this object, and was patented by Beart in the year 1844. The rod connecting the boring-tool with the workmen above is hollow, forming a tube with water-tight joints; into this tube water is introduced, an upward and downward current of the same being gained by allowing the water to flow in one direction in the tube, and in the other in the circular space around it. The strength of this current the inventor considers sufficient to carry up with it the materials which are loosened by the boring-tool. That some loose matter could be so carried is probable, though in a majority of cases it is likely it might be impossible. Another objection to this arrangement is the immense quantity of water necessary, an article which, in sinking a well, is not usually very plentiful until obtained from the well itself.*

Confining ourselves, therefore, to the ordinary system, it will be proper, in the first place, to notice a few preparations which are necessary before commencing the boring itself. Assuming a well to be sunk so deep that we are certain that when the spring is tapped the water will rise a sufficient distance within it, the first consideration will be, can the boring take place from some point in the well itself, or must we work from the surface? The answer to this will depend on the depth of the proposed bore, together with its diameter, and the nature of the ground to be worked into. If the well be under 4 feet diameter, it is difficult to obtain sufficient leverage for any heavy work, if the boring takes place from a point in the well distant from the surface of the ground: in that case we are driven to work from the surface, but, where it is possible to bore

* The system described above was first brought prominently before the public by M. Arago, as the invention of a M. Fauvel. Notwithstanding the countenance of that philosopher and of Dr. Buckland, the objections cited in the text are valid; and practically it has been *shown* that the system could not be worked. At any rate it has been *allowed to drop quietly*.—G. R. B.

from below, it is better to do so for the following reasons, among others: first, there will be a great saving of temporary work above-ground, for the stage the workmen bore from must, if above-ground, be elevated some distance from the surface—20 feet at least—or great waste of time will take place in screwing and unscrewing the rods, &c.; secondly, a less weight of rods will be on the windlass, for, if the boring takes place from a point in the well, the rods need only to be suspended by ropes from the windlass to the stage in the well from which the boring takes place; and there will be an economy of time in screwing and unscrewing the rods, as they may be drawn up without detaching them from each other in lengths equal to the distance of the windlass to the boring stage nearly. To reap the same advantage when boring from the surface, a high pair of shears or a triangle is requisite, which, of course, adds to the expense and trouble.

Supposing it decided that boring should be carried on in the well, care should be taken to fix on the position of the stage or floor from which the work is done; this should be as low as practicable, as may be supposed from what has been said before; but at the same time the stage should be a sufficient distance above the level in the well to which the water will rise. This is a consideration which can be ascertained only by experience and a knowledge of the spring-water level of the district. The stage consists of a stout plank floor, resting on strong putlogs. The flooring is well braced together by planks nailed transversely across the same. In the centre of this floor is a square hole, a little larger than the boring-rods, which therefore can pass through it, but not large enough to allow a small hook apparatus, represented in Fig. 15, which, having the power of holding the rods suspended while they are screwed and unscrewed, will prevent their falling through the stage. From the bottom of the well to above where the water will rise, say to nearly under the boring stage,

wooden trunks, strongly but temporarily secured, are fixed as guides for the boring-tools, permanent pipes, &c. These trunks may be made square, and are fitted by sockets one into the other. Sometimes temporary iron pipes are used instead of these wooden trunks. The permanent pipe to be inserted in the hole bored should be joined together and slung down the well, ready to be fixed when occasion may require. Thus having, we will suppose, bored through the mottled clay, the sooner the pipes follow the better, as the sand underneath is liable to blow up into the bore-hole, or the clay itself, when not dense and stiff, may fall, and to a certain extent choke up the hole. These pipes are either of cast or wrought iron; the latter are generally used for small distances, and the former, as being thicker, for very deep work, where much driving will be required. The lower pipes of the series are usually perforated with small holes when the spring is in sand; but when the water is to rise from chalk or rock, no perforation is required, because the pipes themselves are only requisite when the bore-hole will not stand without them. In many cases in and about London, advantage is taken both of the main sand spring and the chalk springs also; then perforated pipes are driven in the former, smaller pipes and a smaller bore being continued to the chalk. The junctions of the pipes show nearly, sometimes quite, an even face on the outside. The cast-iron pipes have generally turned joints and wrought-iron collars, usually flush on the inside as well as on the outside; if, however, required to be slighter, they may be cast with the vertical portion of a less thickness than the flanges; for if the thickness at the joint be the same in both cases, no advantage, as far as passing tools up and down, is gained by having the internal diameter uniform throughout, though there is a great advantage in point of strength. The collars are sometimes fixed on the pipes with screws; though, when the joints are not *turned, they* are run together with metal: this latter plan

will entirely exclude any bad water which may be met with; but the other mode of fixing is the one usually adopted. The wrought-iron pipes are now seldom riveted, but have thin collars soldered on to the pipes, which are never quite flush outside. The melting of the solder, previously run into the parts to be joined, is accomplished by suspending iron heaters down the pipe; the small heater being made of one, and the larger heater of two, circular pieces of iron.

The pipes are lowered into the well by means of a wooden plug traversed on the under-side by pins or keys of sufficient length to carry the sides of the pipe. A small groove is cut in the pipe to receive these keys, and as soon as the pipe is lowered into its place it may be detached from the plug by merely turning the latter in a direction which will cause the keys to fall back into the depressions, or seats, left for the purpose of bringing them within the dimensions of the interior of the pipe. By means of these keys it is also possible to drive the pipes, by causing them to bear upon its upper end. (See Fig. 24, p. 57.)

The boring-rods are usually made of wrought iron, in lengths of from 10 to 20 feet; it is, however, convenient to employ them of only one length, and to number the rods, in order at any time to have an approximate guide to the depth of the boring. The head of the first rod is made with a hook, by means of which it is suspended to the lever communicating the percussive motion; and below this hook it has an eye formed to receive a transverse bar, which, by being turned by the workmen, communicates the rotary motion (see Fig. 12). The bottom of each rod has a socket, tapped with a female screw, to receive the head of the succeeding rod, which is formed by a male screw fitting into the socket. Under the screwed head there is a swelling out of the rod, indicated in Fig. 13, for the purpose of suspending it during the operation of withdrawal; the projection rests upon the sides of the crow's foot (Fig. 15),

whilst the upper rod is being detached, and the crow's foot itself is supported by the stage upon which the men work.

In borings of small depth the rotary and percussive motions are produced by manual labour; when the depth becomes exceedingly great, however, horse-power, or the

Fig. 12.

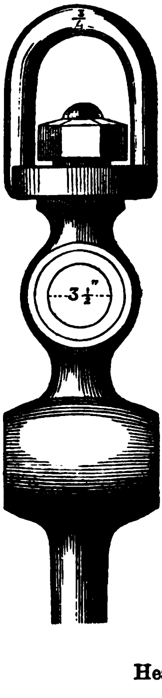


Fig. 13.

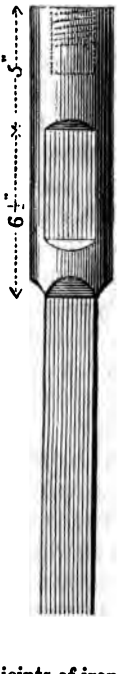
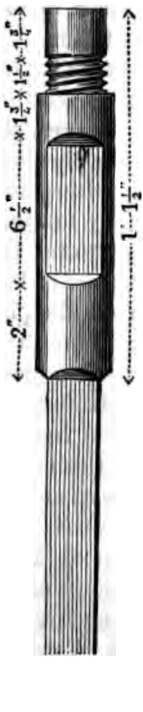


Fig. 14.



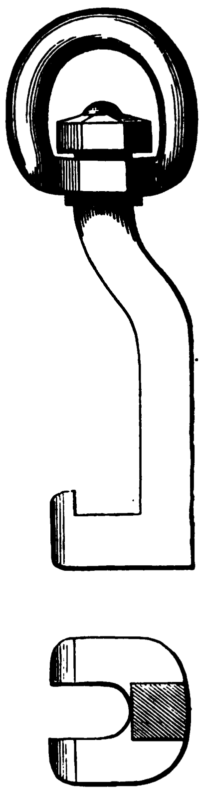
Head and joints of iron rods.

steam engine, must be employed, on account of the weight of the rods. In sinking the wells at Grenelle, M. Mulot used a horse-mill; of late years M. Degousée has employed steam, and at Southampton latterly the rods were raised and lowered by steam-power.

The rotary motion is usually communicated by means

of levers traversing the eye in the position shown in Fig. 12, as before stated; and in tolerably yielding materials, such as clay, sand, soft chalk, &c., no other motion is required to secure the descent of the boring-tool; but in harder materials it is necessary to comminute the rock before the tool can make any progress. The simplest manner of effecting this object consists in suspending the rods by a rope coiled two or three times round the barrel of a windlass, and adjusting the rope in such a manner that if a workman hold one end of the coil tight the friction will be sufficient to raise the rods on the windlass being set in motion. Should the end of the rope the workman holds now be slackened, the coil becomes loose, and the rods descend with a force proportionate to their own weight and the distance they have travelled through. A regular percussive action is therefore gained by keeping the windlass constantly in motion in one direction, the attending workman alternately allowing the rods to be drawn up a certain distance, and then, by relaxing his hold, to fall.

Fig. 15.



From this description of the manner of communicating the different movements to the rods it must be evident that their weight is a very important consideration, and that in order to resist the efforts of torsion and percussion they must be made of dimensions proportionate to the depth of the bore. For depths not exceeding 100 feet, and with a bore-hole of from 2 to 3 inches, a rod 1 inch square, weigh-

ing $3\frac{1}{3}$ lbs. per foot lineal, will suffice. A depth of about from 600 to 700 feet, with a bore-hole of 6 or 7 inches diameter, will require rods measuring at least $1\frac{5}{8}$ inch on a side, weighing 8·8 lbs. per foot lineal; whilst for such depths as the wells at Grenelle or Southampton they would require to be at least 2 inches on the side and weigh $13\frac{1}{3}$ lbs. per foot. The weight thus increases as rapidly as the depth; and when the latter is considerable, inasmuch as the upper parts bear upon the working end, the danger of rupture also augments.

At very great depths not only does the weight of the rods become an evil of serious importance, but when the percussive motion is given to the rods they vibrate with great force, and striking against the sides of the bore, they are likely to detach portions of the rock, which would, in that case, fall upon the top of the tool. This danger has been sometimes obviated by using lighter and more voluminous rods; indeed, as the bore-holes are usually filled with water, and therefore the rods lose a portion of their weight, it is advantageous to increase the volume, even if the weight remain the same. M. Degousée effected the desired object by using wooden rods surrounded by iron bands, and with iron screwed heads (see Fig. 16); or by using tubular wrought-iron rods of the same weight per foot lineal as the solid rods, but which, owing to their displacement of water, did not act so injuriously upon the lower portions, whilst, at the same time, their volume rendered them less liable to vibrations. The wrought-iron tubes present this advantage over the wooden rods, that they are more calculated to resist the effort of torsion; but the latter, on the contrary, are lighter.

Beyond a certain depth it is dangerous to exercise a percussive action of such power as to expose the lower rods to be broken. Many accidents have occurred in borings from the neglect of this consideration, and perhaps the *well of Grenelle* furnished a greater number of illustra-

tions of the necessity for the abstract theoretical calculations of the weight and description of the rods to be employed than any well ever executed; it was marked by a continued series of accidents from this cause. Indeed, when borings exceed 1000 feet, the systems above described, viz., the use of wooden or tubular rods, will not suffice to obviate the danger of crushing the lower portions of the boring-tool, and the slide-joint, invented by Œuyenhausen, is necessary to insure their safety.

Fig. 16.

Wooden rod, bound with iron.

When this joint is used the rod is divided into two portions; the upper one being counterbalanced by a weight suspended to a lever, and the lower one only allowed to act by percussion,—the weight of the latter rarely exceeding from 12 to 16 cwt. Between these portions the slide-joint is introduced. It consists of two parts (see Fig. 17) able to slide upon one another for a distance of about one foot, and so arranged that during the descent one becomes detached from the other. The upper part is balanced by the counterpoise. When the boring-tool is allowed to descend after it has been raised for the purpose of getting the blow, it will strike the bottom simply with a weight equal to that of the lower portion, and the upper portion will descend gently through the distance of 1 foot until it rests upon the collar. Should it be required to bore without percussion, the slide-joint is suppressed, and a common rod substituted; in that case also the lighter and weaker rods are replaced by stout bars able to resist an effort of torsion.

As the boring-tool is in all these operations the acting part, its form varies according to the object proposed to be attained and the resistance of the ground to be traversed; the first condition being that it correspond with the dia-

Fig. 17.

(Euyenhausen's slide-joint.

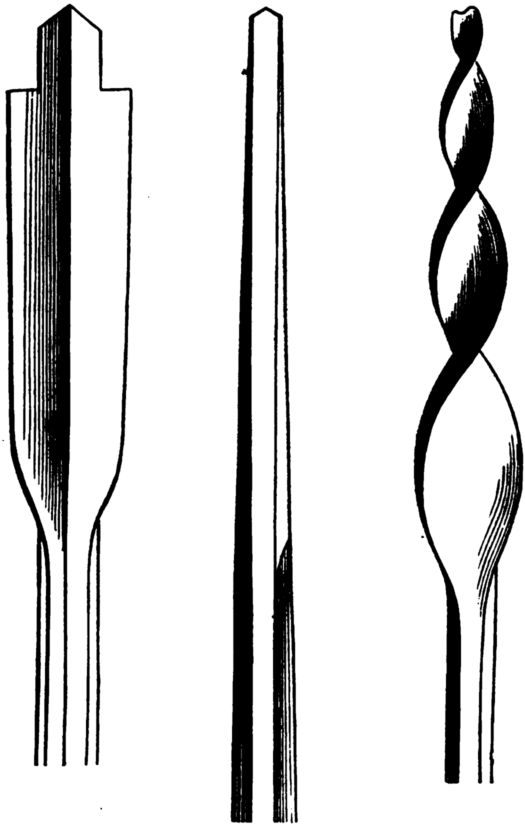
meter of the bore. Each tool is shut upon a rod carrying a joint, the joint being usually a screw, with the female screw downwards. The boring-tools may be divided into four classes, according to the object they are intended to effect: 1, tools for cutting or comminuting rocks by percussion (see Figs. 18, 19, 20); 2, tools for extracting soft or disintegrated materials (see Figs. 21, 22, 23); 3, tools for cleansing and enlarging, or equalizing the bore-hole; 4, tools for extracting any broken rods, or for accidental works, or for raising or lowering the tubes.

The tools for percussion consist of an infinite number of chisels whose forms do not appear to require so many modifications as workmen usually introduce. In hard rocks, such as the oolites, a plain chisel with a diameter equal to the hole to be bored, and with a cutting edge, is sufficient. The shape represented in Figs. 18 and 19 is adapted to harder rocks, such as the sandstones, because it divides the action. The twisted chisel, Fig. 20, is adapted for softer rocks.

Boring-tools are usually made upon the same principle as wood augers; that is to say, they consist of a point which disintegrates the rock by its rotary motion; of a species of tongue, or occasionally of a clack, to support the loosened materials; and of the body of the auger, which contains these materials, at the same time that it serves to enlarge the hole. It must be evident that these augers can only be used in soft ground, for they would not exercise any action upon hard rocks. Their forms differ according to the nature of the strata traversed,

being open and cylindrical, in clayey or calcareous lands possessing a certain degree of cohesion. They are closed, and sometimes conical, in running sands; and in this case

Figs. 18, 19, 20. Chisels.



it is also necessary occasionally to use closed augers with clacks, or even a movable bullet, to prevent the accumulated matters from falling back into the bore.

The vertical position of the rods is insured by attaching

to them four guides fitting closely into the bore-hole, yet allowing the free action of the tools themselves.

The tools used for enlarging a hole may consist either of

Fig. 21.

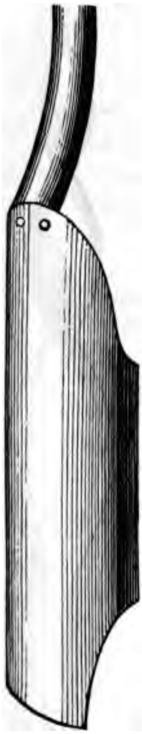
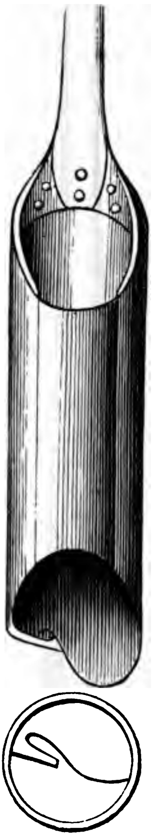
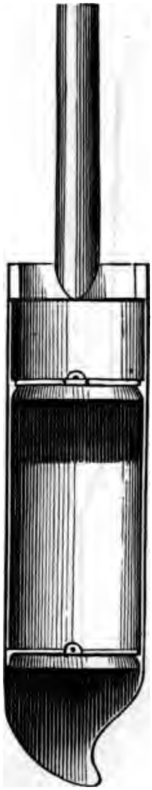


Fig. 22.



Auger.

Fig. 23.



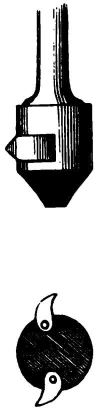
Auger, with clacks.

the chisels (Nos. 18, 19) already described, or of augers with increasing diameters. M. Degousée used a very simple tool for the purpose of equalizing the dimensions of a bore,

which consisted of two iron plates, from 5 to 7 feet apart, between which square bars with cutting edges were inserted vertically. These bars, if made to turn in the hole, would of course act upon the sides for their whole height.

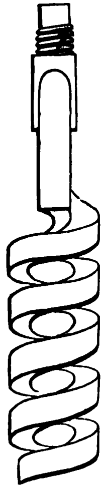
The tools for the purpose of withdrawing any broken rods consist of three principal descriptions: a species of hook which is made to fit under the projecting parts of the rod; a screw tap, the mouth of which is larger than the end of the rod to be raised; and a spring-clutch, so arranged that the rod will allow the catches to descend, but in the upward motion they are pressed upon the rod by means of steel springs. Fig. 25 represents a tool used to withdraw portions of rods. Should these means fail, no resource is left but to thrust the rod aside, into the bore, and continue the work beyond it.

Fig. 24.



Tool for lowering tubes.

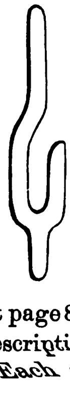
Fig. 25.



Screw for raising broken portions of rods.

The scotch, Fig. 26, is used for the purpose of allowing the rods to rest on the wooden stage, or for that of unscrewing the different lengths. The tool represented by Fig. 24 is for the purpose of lowering tubes into their places; when open, the tongues bear against pins upon the bottom of the tubes; by turning in a reverse direction, they fall back into the seats prepared to receive them; this tool has been already referred to; another instrument for effecting the same purpose will be found at page 80.

Fig. 26.



Scotch.

It must not be understood that the above description comprehends every tool used by well-borers. Each con-

tractor, in fact, has his own system, and the nature of the ground to be operated upon varies so much in one locality from what it is in another, that every case requires to be treated, as it were, upon its own merits. See illustrations in the works of MM. Degousée and Burat.

In conclusion it may be desirable to give the following specifications, one of which was used by the late Mr. Swindell for a well only, and the other for a work comprising both well-digging and boring.

Specification.

Conditions and particulars to be observed by the contractor during the sinking, steining, and boring a well, situate at———, for———, and to be executed under the superintendence of Mr. J. G. Swindell, architect.

The work to be carried steadily forward from the commencement to the completion of the same, a sufficient gang or gangs of men being always employed during the usual working hours. No deviations to be made in any manner from the covenants and agreements in this specification, and, in case any work should not be to the satisfaction of the above-named J. G. Swindell, the same to be immediately altered and amended. The care of the works rests with the contractor alone, the owner not being accountable for anything stolen, or for any loss or damage; and in case any unforeseen circumstance should take place, or any accident, of whatever kind, should arise, causing additional trouble,—workmanship, or making good such work,—is included in the contractor's accountability, and is to be rectified or made good by him without any extra or additional charge beyond the amount of the contract.

The contractor is to provide all labour, tools, tackle, buckets, windlasses, ropes, boring augers, and all and every tool or requisite for carrying on the works; the bricks, sand, cement, and pipes for lining the bore-hole being alone found *by the employer.*

In case the contractor shall delay the work or refuse to proceed with the same, the employer, after having given the contractor one week's notice in writing, is at liberty to take possession of all materials or tackle that are on the ground belonging to the contractor, and which he, the said contractor, forfeits by delay or refusal. The employer shall also be at liberty to engage other workman or workmen, and to deduct all the cost and charges thereof, from money due for previous work done by the contractor, the said contractor forfeiting by his delay or refusal all such money.

The amount of the contract-money to be paid by weekly instalments, calculated to reserve one-half of the cost of the works done, and subject to a certificate from the architect that they are going on to his satisfaction, and are sufficiently advanced to warrant such payments. The balance of the amount due to the contractor on the completion of the work to be paid within one week after the fixing of the permanent pumps.

Digging and Steining.—To excavate a well 4 feet diameter in the clear when the steining is finished, and of a depth of 200 feet; place the earth removed conveniently for wheeling away, the wheeling being performed by the employer. Stein in 4½-inch brickwork the said well; the bricks to be laid dry, with, at intervals, three courses set in cement, such intervals to be regulated by the nature of the clay, but in no case to exceed 5 feet apart; shut out all land-springs by bricking entirely in cement and puddling behind the same. Ten feet from the surface of the ground the steining to be 9-inch work, laid in cement, so as to block out surface drainage. Pump or bale out any accumulated water that may occur during the progress of the work. Fill up all putlog holes, and leave the steining in a perfect state.

Boring.—At the bottom of the said well, when it has attained the depth of 200 feet, insert, full 2 feet into the bottom, a cast-iron pipe, 12 inches diameter and 9 feet long;

then bore with an $11\frac{1}{2}$-inch auger, shell, or other tool requisite, and fit into the hole 8-inch wrought-iron boring pipes of the usual construction; after attaining a depth of bore at which the 8-inch pipes will no longer drive, insert 6-inch; make all joints in the said pipes secure and good, providing the solder and the materials for the purpose. The lower pipes to be well driven into the spring, and to have holes in the same to allow sufficient waterway; the upper pipe to stand 12 feet above the bottom of the shaft. Provide and fix all temporary wooden trunks before commencing boring, and do all temporary work required during the progress of the boring and other work.

Contract.—I, ———, of ———, do hereby engage and agree with ———, of ———, for and in consideration of the sums undermentioned, to do all the labour, finding all tools and tackle necessary in digging, steining, and boring a well, to be done in strict and literal accordance with the covenants and directions of the foregoing specification. The same to be done in the most workmanlike manner and to the entire satisfaction of Mr. J. G. Swindell, architect. The contract-money to be as follows, viz.:—For executing completely the 200 feet of well-work ———; for the first 100 feet of boring at the rate of ———; the next 20 feet an increase of ——— per foot, and increasing per foot every 20 feet deep the sum of ———. I hereby undertake to go on with the work till ordered in writing by my employer to stop, and to satisfactorily complete the work, without any extra charge beyond the said money mentioned above, which is to be calculated only to the depth of the work actually done.

N.B.—The reason no prices are given in the above is because so doing might greatly mislead, a variety of matters influencing the expense of the works in such uncertain operations as well-work: framing the contract so as only to pay for what is actually done is fairest both to the employer and contractor, and is therefore adopted in this

contract. In the following work it was expected that water would be found about 85 to 90 feet from the surface; experience showed that 81 feet was the point where the spring was entered. Contracting, therefore, for 50 feet certain, and then at an increasing schedule of prices, was considered the best method: here all things were found by the contractor.

Specification.

Specification of certain works required to be done in sinking and steining a well for ———, of ———, to be excavated in a field called Great Daws, in a part of it to be pointed out to the contractor.

Excavator.—To excavate a well 4 feet diameter in the clear when finished and steined; to be sunk as deep as directed by Mr. Swindell, architect, under whose superintendence the work is to be done; provide all buckets, tackle, ropes, windlass, &c., necessary for removing the products of the excavation, which are to be placed or piled in a part of the field where directed, within 60 feet of the opening of the shaft; provide all shoring, boring augers necessary for feeling the work, as the excavation proceeds; remove all extraneous water, and do all things necessary for completing the works.

Steining.—The bricks to be new, sound, hard, square, well-burned gray stocks. The steining to be 4½-inch work, and to be laid dry in the most careful and approved manner, between the courses laid in cement, which cemented rings are to be three courses thick, and to occur as close as may be necessary for the stability of the work, never exceeding 5 feet apart. Where land-springs occur, or in bad ground, the steining to be executed entirely in cement, and puddled behind. The first 4 feet from the surface to be steined in 9-inch work set in cement. The best Roman cement and sharp Thames sand to be used; the former to be gauged with half sand.

CHAPTER VI.

NOTES ON ARTESIAN WELLS MADE BEFORE 1851.

The Wells at Trafalgar Square, London.

FROM the position of the fountains, the discussions their appearance gave rise to, and the circumstances attending their execution, this national work is well worth attention: a descriptive sketch is therefore given of the wells, and of the engine for raising the water. The water is supplied by two wells, connected together by a tunnel, or driftway, which is run in the clay at a point lower than the position in the wells to where the water rises; the wells and tunnel are calculated to hold, when the water has attained its maximum height, 122 000 gallons. One of these wells is in Orange Street, and about 180 feet deep, with a diameter of 6 feet; the other is in front of the National Gallery, and is of very nearly the same depth, with a diameter of 4 feet 6 inches; the driftway is 6 feet diameter, and occurs about 5 feet from the bottom of the shafts; this driftway, or tunnel, is horizontal. The boring, which commenced at the bottom of the shaft, was continued to a greater depth in the well opposite the National Gallery than in the one in Orange Street; the total depth from the surface being, in one case, 395, while, in the other, it was about 300 feet. The use of the tunnel is almost self-evident; it acts, as may be supposed, as a reservoir to store the water while the engine is not at work; thus insuring a sufficiency to supply the pumps, even should they draw the water away from the well faster than the same is supplied by the spring. The strata passed through by the two wells may be thus stated upon the authority of a section published in the *Illustrated London News*.

Well in front of National Gallery.

Made ground	9 feet.
Gravel	5 ,,
Shifting sand	7 ,,
Gravel	2 ,,
London clay	142 ,,
Thin layer of shells.	
Plastic clay	30 ,,
Green-sand, pebbles, &c.	11 ,,
Green-sand	42 ,,
Chalk.	,,

Total depth to chalk is therefore 248 feet, and total depth of well and bore 395 feet.

Well in Orange Street.

Made ground	15 feet.
Gravel	5 ,,
Loam and gravel	10 ,,
London clay	145 ,,
Thin layer of shells.	
Plastic clay	30 ,,
Gravel and stones	10 ,,
Green-sand.	35 ,,

Chalk, which, according to the above, is distant from the surface 250 feet, the bore being continued to a total depth from surface of ground of about 300 feet.

The pumping engines are on the Cornish plan; one is of the usual construction, having a beam, and the other, which is chiefly required as a reserve engine, is direct-acting, that is, the beam is dispensed with, and the piston-rod of the engine connected by rods directly on to the pumps. Though the mode of action of these and other Cornish engines cannot be thoroughly explained without complicated drawings, yet the following will give some idea of it, and, if attentively read over, while watching the working of an engine of this description, may assist the reader in the comprehension of its action. The steam acts on the piston, if the engine be a beam engine, only during its downstroke: to regulate this, a valve is required, situated so as to open and shut the communication between the steam in the boiler and the top of the cylinder, in which the piston slides, and a similar valve opening a communication between the top and the bottom of the cylinder: now, should this be open, the steam valve being shut, the piston will rise, for the counterweight at the opposite end of the beam will pull the piston upwards, and the steam will circulate from the top to the bottom of the cylinder. A third valve is also required to open and shut a communication between the bottom of the cylinder and the vessel in which

the steam is condensed; so that the steam, which in the down-stroke of the piston caused its motion, is, after having changed its position, by the opening of the equilibrium valve, from the top to the bottom of the cylinder, then by the opening of the exhaust valve, let into the condenser. With this explanation, the double stroke of the engine may be understood: supposing the steamvalve and exhaustvalve, opened by the preponderance of weights, released by the cataract, or instrument for regulating the distance between the strokes, a downward motion of the piston commences, when at about one-third of its stroke, or less, the motion of the engine shuts the steam valve, the exhaust valve remaining open, the expansion of the steam shut in the upper part of the cylinder causes the piston to continue its motion to near the bottom of the cylinder, and at a point a little above the end of the stroke the exhaust valve is shut. The engine is now quite stationary; at the proper period the cataract releases the equilibrium valve weight; the valve rises, and the up-stroke is performed by the aid of the counterweight, as before remarked. On the engine shutting the equilibrium valve, the up-stroke of the piston is stopped, and, after a definite period, by the action of the cataract, the steam valve is again opened. The steam being condensed, the under-side of the piston, it is almost needless to remark, is in vacuo during its down-stroke: this condensing apparatus is not common to the pumping engine alone, but is usually applied in all large engines. The advantage of condensation is equivalent to an increased pressure of steam in the boiler, for it is manifestly the same thing in effect to withdraw a certain resistance opposed to the motion of the piston as to add additional urging force, the resistance being retained; and if, further, this resistance can be removed with less expenditure than the increased pressure can be gained, it is clear its removal is more desirable than increasing the pressure of steam. *To condense* the exhaust steam, we require plenty of cold

water; to increase the boiler pressure, we require more fuel, and circumstances will determine which of these two it will be best to expend.

Artesian Well at Camden Station.

This work differs from the former example in the description of steam engine and arrangement of the pumps, for as the engine is required to do other work besides pumping, the ordinary pumping engine is inadmissible. The well, the pumps, and the motive power are therefore mentioned in order. Firstly, the well: this is sunk to a depth of 180 feet, of a diameter in the clear of 9 feet 6 inches, and the steining is executed throughout the entire depth in cement. For 28 feet from the surface, unusual precautions are taken to exclude land-springs, &c.; they are, first, an inner steining of half brickwork set in cement; next, segmental cylinders of iron; next, a thickness of about 9 inches of concrete; and lastly, behind all this, a 9-inch steining of brickwork. From the depth of 28 feet from the surface, the steining is 14 inches thick, and bonding curbs of iron occur at intervals. The boring, which commences at a depth of 180 feet from the surface, is continued for 220 feet, and is of a diameter of 12 inches. The water rises in the well 36 feet from the bottom, or to a height of 44 feet from the surface of the ground. The well-work was executed by Mr. Paten, of Watford; the pump-work and engines were made by Messrs. Bury, Curtis, and Kennedy, of Liverpool. The ground passed through in the execution of this well was as follows:

STRATA TRAVERSED.

Made ground	9 feet.
Loam and gravel	6 ,,
Black earth	3 ,,
Blue clay	144 ,,
Mottled clay	36 ,,
Carried forward	198 feet.

Brought forward . .	198 feet.
Green sand	1 ,,
Pebbles	2 ,,
Mottled clay	8 ,,
Plastic clay	17 ,,
Loam and sand	5 ,,
Pebbles and sand	2 ,,
Bed of flints	1 ,,
Chalk	166 ,,
Total depth	400

The boring-pipes are continued 60 feet up the well, the water being admitted from them by a sluice, which is situated about 4 feet from the bottom of the shaft. This sluice is worked by a handle placed above the water-level; the pipes themselves are steadied by stays, which are secured to the brickwork of the well.

Secondly: the pumps are in two pairs, each consisting of a lifting-pump for the lower, and a plunger-pump for the upper lift. This arrangement of four pumps is used to insure uniformity of motion, for the steam engine being double-acting, that is, giving out as much power during the up as the down stroke of the piston, requires an equal resistance for each stroke. The lifting-pumps empty their water into a wrought-iron cistern, which is about 4 feet deep and 3 feet 2 inches over, the back of it being curved to suit that of the well; the plan of the cistern being that of a sector. The suction-pipes of the plunger-pumps are inserted into this cistern; the plungers are 8 inches diameter, and the buckets of the lifting-pumps, $8\frac{5}{8}''$. The rising mains of the latter are 11 inches diameter; the mains of the plunger-pumps are of course smaller, the working parts of the pumps being outside, and not surrounded by the mains, as the lifting buckets are. For the same reason, only one main is required for the plunger-pumps; at the bottom of this is situated an air vessel, which is an apparatus whereby a constantly uniform stream of water flows from the main; its construction is very simple. It may be

described as a vessel larger than the rising main, and into which, through an air-tight opening at the upper end, the main dips so as nearly to touch the bottom of the vessel; water from the pumps being injected into this vessel will compress the air included in the space between the orifice of the main and the upper part of the vessel; the elasticity of this compressed air will therefore continue to drive the water which has risen above the orifice up the main during the interval that the pumps are stationary, which is at the period of the change of stroke.

Thirdly: the motive power for working the pumps consists of a high-pressure beam engine of the usual construction, which, as before remarked, performs other work as well as pumping. This engine is of 27 horse-power. The power required for raising the water can be determined by any one, as all the data are here given for the calculation, it being borne in mind that the cistern into which the water is forced is 40 feet above the surface of the ground. The steam engine has a 4-feet stroke, and the motion of the pumps being taken off the beam, at points respectively midway between the centre of the beam and the two ends, gives as the stroke of the pumps 2 feet. The speed at which the engine travelled when the author visited the works was twenty-one revolutions per minute. The duplicate boilers for this engine are of the Cornish description; they are 5 feet 10 inches diameter, and 22 feet long; sufficient steam is generated by one of them working singly, the other is kept as a reserve. The strength of the spring was tested when the works were completed, and the following was the result. The engine began to work at nine o'clock in the morning, and by continual pumping till twelve, lowered the water 11 feet 6 inches; by three o'clock, the engine still working, the water was lowered 6 inches more; at that point no further diminution was remarked. The water is remarkably soft, and for domestic purposes is excellent, but it does not answer for supplying the boilers

of locomotive engines. Annexed is an analysis of the water of the well under consideration, as also of that drawn from the wells belonging to the Railway Company at the Watford and Tring Stations: all these are sunk in the chalk formation, yet a great difference exists in the constituents of the impurities of the water. The analysis in all cases was made by R. Phillips, Esq.

Situation.	Sulphate Soda.	Carbonate Soda.	Muriate Soda.	Carbonaceous Matter and Trace of Silica.	Sulphate Lime.	Carbonate Lime.	Total Solid Matter.
							Grains.
Camden .	13·00	17·60	11·10	2·30	..	..	44·00
Watford .	..	..	1·90	1·32	·94	19·54	23·70
Tring .	..	..	1·38	1·61	1·09	14·72	18·80

The quantity of water experimented upon in the above analysis was one gallon in each case. The above particulars of the Camden well were obtained by the kindness of R. B. Dockray, Esq., C.E., through the means of documents in the Engineer's Office, Euston Station, and from personal examination of the pump-work, &c., in the well itself.

Well at the Hanwell Lunatic Asylum.

This work, which was executed a few years since, is remarkable on account of the height to which the water rises; indeed, the district is well suited for a purely Artesian well, and in this case it is quite evident that, had the well been entirely bored, the same amount of water would have been obtained, deducting the retarding action caused by the friction of the water against the sides of the bore-pipe. In the "Sixty-eighth Report of the

Visiting Justices of the County Lunatic Asylum at Hanwell" is a notice of this well, from which the following is compiled. The section of the ground passed through is as follows.

STRATA TRAVERSED.

	Feet.
Vegetable soil, sand, and gravel . . .	20
Blue clay, with some brick clay on the top, and veins of stone occurring at intervals .	168
Indurated mud and sand	22
Pebbles and shells	2
Mottled clay	23
Sand and water	2
Mottled clay	13
Indurated sand and mud	9
Clay	8
Green-sand and clay	8
Bed of hard oyster shells	3½
Pebbles	3½
Flint stones bored into	8
Total depth . . .	290

In sinking this well, the shaft was carried down for the first 30 feet of a diameter of 10 feet; from that point the diameter was 6 feet to that part of the mottled clay in which the iron cylinders were affixed. The cylinders were then lined with a brick steining, and the boring was continued from thence to the bed of flints in which the work was discontinued. The supply of water from the sand-spring rose to within 16 feet of the surface of the ground; from the pebbles overlying the flints, the water rose to a further height of 8 feet, and from the bed of saturated flint stones, the water rose so as to overflow the surface at the rate of 100 gallons per minute; and, 26 feet above the surface, the water overflowed at the rate of 23 gallons per minute. The supply proving so great, the large diameter of the first 30 feet of well was found useless, and a rising main of iron was fitted to a cap which was inserted at that part of it where the 6-feet diameter commenced.

The temperature of the water is about 55° Fahrenheit, and contains in each gallon 48 grains of solid matter, consisting of salts of lime and soda, with a trace of iron.

Messrs. Verey's Well, Kilburn.

This work was executed under the superintendence of the late Mr. J. G. Swindell about the year 1848: the diameter in the clear for 250 feet in depth is 4 feet: after that, boring commences, and is carried down to the sand-spring of a diameter of 8 inches, and to a total depth from the surface of about 280 feet. The rise of water is to about 150 feet, or rather less, from the surface. The original intention in sinking this well was to have bored after attaining a depth of 200 feet (the water-level being well known in this district); but had such intention been persevered in, fears were entertained that the 50 feet of water in the well, being only the upper head of the spring, would be insufficient to supply the wants of the brewery: the extra 50 feet of digging were therefore ultimately determined on, and the experiment detailed in the following pages proves the view taken to have been correct; for if pumps be fixed at too high a level above the spring, the hydrostatic pressure of water is insufficient to cause the water to rise in the well fast enough to supply the pumps, even should they be small ones. The works were commenced in April, 1848, and for the first 10 feet the brickwork was in cement 9 inches thick, to exclude land-springs from the well: about 25 feet were executed the first week, and after that the work averaged about 20 feet to the week, some weeks a little more, some a little less; the stiffness of the clay and the claystones, or septaria, which were found at intervals, affecting the speed of the work. The London or blue clay, which was soon arrived at, extended to a depth of 235 feet,—the mottled clay, pebbles and sand followed much in the order of the sections before given,—while in the mottled clay the steining was not left

unsupported with such impunity as in the blue clay: it is of a more soapy or slimy nature, and exposure to the air, together with these properties, renders it more likely to allow the brickwork to slip. On the execution of the steining it is only necessary to remark that the work was laid partly in cement and partly dry, and of a thickness of 4½ inches. The cement used was blue lias (Greave's patent), and the bricks partly stocks and partly malm paviours. The cement was used stale and mixed thin, since otherwise it would have become partially set in being conveyed down the shaft to the workmen, as, when near the full depth, the time of journey down the well was nearly of three minutes' duration.* The boring pipes were of wrought-iron, the lower lengths perforated, the junctions being tinned in the usual manner. On obtaining the water, the quantity was tested by the aid of a temporary pump, the application of which is also useful in clearing the work, and ascertaining if any sand has blown into the well: this pump was an ordinary lifting pump of 6 inches diameter, and working with a stroke in the barrel of about 9 inches; the rising main was bolted directly over the pump-barrel, which by it was thus suspended in the water; the main, on its passage up the well, was steadied by timbers; the rods worked by this arrangement in the rising main, and were carried to the top of the well, where motion was given to them by eight men: the result of the experiment was, that the pump, which threw about 24 gallons per minute,

* The manner of using cement described in the text is one so contradictory to all the laws affecting that class of materials that it is not possible to protest against it too strongly. In such a case as this, if it had been necessary to mix the mortar, or cement, above ground, the proper material to have been employed would have been blue lias *lime*, or some hydraulic lime whose rate of setting would have been sufficiently slow. Mortar made with an excess of water loses nearly all its valuable qualities; when used stale it is also inferior to that which is fresh; and the same remarks apply, with even greater importance, to every description of cement.—G. R. B.

lowered the water about 33 feet, but no further, thus proving the strength of the spring when a head of 33 feet of water was taken off. Here the advantage of drawing the water from a point under its surface, as far as practicable, is made manifest; indeed, the question is one turning on a law of hydrostatics, well known and easily calculated. The pumps were executed by another party, and it may suffice to say that they are of the description technically called three-throw pumps, and very good of their kind. The cost of executing this well, exclusive of the pumpwork, both temporary and permanent, was about £200.

Well at Hampstead Heath, belonging to the Hampstead Water Company.

This well was sunk in the year 1833, down to the main sand-spring, a depth of about 320 feet, and of a diameter of seven feet. Subsequently, as a rather greater supply of water was desired, a bore was carried into the chalk. The steining of the well is 9-inch work, laid dry, between rings set in cement; the back steining has its cement rings midway between those of the front steining. The lower part of the steining is held up by four tie-rods, which are bolted to a cast-iron curb let into the brickwork some distance up the shaft. The section of the ground passed through during the two operations of digging and boring is given below. The situation is on the lower Heath, where the Bagshot sands are wanting.

Yellow clay	30 feet.
Blue clay	259 ,,
Plastic clay	40 ,,
Sand	49 ,,
Bed of flints, very thin, chalk hard	40 ,,
,, ,, soft, with water	4 ,,
Chalk hard, no water	28 ,,

From this section it will be seen, that after passing the chalk spring, the hard chalk underlying it supplied no

water, thus proving that in sinking wells in this formation, when it is very hard, no water can be expected till long lines of flints, fissures, or softer chalk, are arrived at. Mr. Hakewell, the Engineer under whose orders this boring was executed, paid particular attention to the conditions of the supply from the chalk, and the fact that no water was furnished by the hard bed under the spring influenced his proceedings in the execution of the well at Kentish Town. The water is raised in this well by means of three lifting pumps, situated at different heights up the shaft. Each lift averages about 100 feet, and the sizes of the pumps are 8⅝" diameter of bucket, by a length of stroke of 2 feet 3 inches; the lowest pump is slung in the water by having its rising main, which is of larger diameter than the bucket, secured by flanches and bolts to cast-iron girders, arranged for that purpose in the well, where the two lower lifts terminate. The pump-rods pass through stuffing-boxes from inside the rising main. The cisterns, from which the second lift draws from the first, and the third from the second, are very small, being only branched from the rising main, and in capacity but little larger in diameter than the pump-barrel, just in fact sufficient to hold a supply for the higher lift. The rods, when inside the mains, are steadied by triangular guiding pieces encircling them, and, where outside the mains, they pass through wooden cleats, which are secured to cast-iron girders. Situated at the top of the well is a cast-iron framing, with upright guides. Between these guides work cast-iron wheels; to the axle of these wheels the pump-rods, and also the connecting rods from the cranks, are attached; thus, though the tendency of the crank in its revolution is to pull the rods from a vertical line, the effect of the pulleys is to keep their motion in a straight one.

Some important observations may be made upon the results of the wells described above, all of which are sunk in what is called the London Basin. Firstly, In the case

of the Camden Town well, the quality of the waters is such as to show that the whole supply is furnished by the loam and sands of the basement beds of the London clay. The boring in the chalk, under these circumstances, was worse than useless, for it only let the water from the sands into a part of the subjacent formation, which was likely to be more absorbent than the surface, because at the junction of any two strata there usually exists a layer of silt or clay which renders the escape of water from the upper to the lower rather difficult. This well may be considered as having been carried down 166 feet deeper than was necessary.

Secondly, In the chalk itself there does not appear to be any other indication of the flow of water sufficient to guide the operations of the Engineer, than what is furnished by the materials traversed. The water circulates through it principally along the lines of fissures, and not by general permeation of the whole mass, owing to its general porous nature and its close texture. It happens, however, especially when it underlies some impervious stratum, that the body of the chalk itself is saturated with water, and a portion is left free to circulate upon any retentive layer which may exist within it. The layers of flint, which sometimes occur in regular stratification over large areas, serve to hold up this free portion in the upper or soft chalk; and it therefore must be upon the top of these layers that we must seek for a supply to a well sunk in this formation, unless any water-bearing fissure be traversed. In the lower members of the series, the comparatively speaking impervious beds of the chalk marl perform the same function of water-bearing strata that the beds of flint do in the wells hitherto sunk near London.

The very remarkable work, by Mr. J. Prestwich, upon the "Water-bearing Strata of London," should be in the hands of every person who desires to become acquainted with this branch of Engineering.

Well at Fort Regent, Jersey.

This work has been described by Major H. D. Jones, R.E., in the "Professional Papers of the Corps of Royal Engineers." The following quotation from parts of his description will no doubt be acceptable to the reader:—

"Fort Regent was constructed during the late war between Great Britain and France. The works were commenced about the year 1806. The fort is erected upon the Town Hill, a bold promontory to the south of the town of St. Helier, which it commands most completely, the town being built at the foot of the rock. The summit of the hill was above 170 feet above the level of high water. In its character it very much resembles Gibraltar, a bold rocky feature, rising abruptly from the sea, and having scarcely any perceptible connexion with the hills to the northward and eastward, which encircle the town in those directions. The South Hill is formed of compact syenite, weighing 165 lbs. per cubic foot. The rock is stratiform, with vertical joints; the general direction is east and west. There were no springs upon the surface of the hill, nor anything indicating on the face of the scarped rock that it contained such an abundant supply of water; it must, consequently, have been upon the conviction that water would be found by sinking to the same level as the water stood at the Pigeon Pump, in Hill Street (240 yards distant from the point where the well in the fort has been sunk), that Major Humphry, the commanding Engineer, was induced to recommend the attempt being made. The operation, although it cost much time, labour, and expense, has been most completely successful. After sinking through 234 feet of compact rock, and upon firing a blast, the spring was laid open, the water from which immediately rose in the shaft to a height of 70 feet, and has rarely since been lower. During the progress of the work, water had been found at different points, but not in any quantity

sufficient to retard the workmen, until the lucky blast above mentioned, when it poured in like a torrent, to the great astonishment of the miners who were suspended in the bucket, waiting the effects of the explosion." The temperature of the water in this well is 50° Fahrenheit. Some further memoranda from the same source are:—
"The following details, extracted from the office books, will afford some idea of the difficulty of the operation, and the time and labour consumed in sinking the well. The work was commenced in December, 1806, and continued night and day until November, 1808.

Commenced 1806.	Number of Miners per month.	Feet sunk per month.	Price paid per foot.
			Livres.
December . . .	14	13	60
1807.			
January . . .	12	8½	72
February . . .	12	3	96
March	12	9	108
April	—	—	—
May	12	5	120
June	12	11	108
July	12	8½	108
August . . .	12	10¼	111
September . . .	12	10	108
October . . .	12	9¼	108
November . . .	12	9	108
December . . .	12	9	108
1808.			
January . . .	12	9¼	108
February . . .	12	7½	108
March	12	10¾	108
April	12	9	108
May	12	12¼	108
June	12	13	108
July	12	10	108
August . . .	12	11¾	108
September . . .	12	9¼	108
October . . .	12	9	108

Average cost, 10s. per foot.—Total expense, £2 599 8s. 7½d.

"There were expended, during the progress of the work, of the following articles, the undermentioned quantities, viz.:—

Candles	976 lbs.
Coals	1,659 bushels.
Gunpowder	2,848 lbs.
Lamp oil	82 gallons.
Miners' tubes	9,852.

"There are two cisterns capable of holding 8 000 gallons each. The water is pumped into them by machinery, to be worked either by horses or men, the same machinery being applicable to the working of a bucket in case the pump should be out of order. The pump is four inches diameter, with brass bucket and valves, with 195 feet of wrought-iron rod, jointed every ten feet, and eighteen 10-feet lengths of 5½-inch iron pipe. Cost £495 15s.

"The machinery for working a bucket from the horse-wheel, independent of the pump, consisting of a barrel on the horizontal shaft, with clutch-box, lever, and pulleys for leading the ropes, cost about £35. The total expense, including the labour in fixing machinery or incidental expenses, amounting to £667 15s. Thus, for a sum little exceeding £3 000, there is obtained for the garrison an inexhaustible supply of excellent water. Twenty-four men, working for two hours, without fatiguing themselves, can with ease pump into the cisterns 800 gallons of water."

Artesian Well at Grenelle.

This well was sunk at the expense of the town of Paris, for the purpose of supplying the abattoir, and the district or quarter of Grenelle, under the directions of M. Mulot.

At St. Ouen and St. Denis, near Paris, Artesian wells had already been sunk through the tertiary formations, until they reached the sands which lie upon the chalk; and a copious supply had been obtained from them. But at Grenelle it was known that so great a difference existed in

the geological structure of these formations, that it became necessary to resort to some other source. The "calcaire grossier," in fact, of the more northerly parts of Paris is replaced at Grenelle by a series of marls and clays, which do not allow the free passage of the subterranean sheet of water. M. Mulot, then, reasoning upon the results obtained by the wells at Elbœuf and Rouen, considered that it would be necessary to traverse the chalk formation itself, and to obtain a supply from the lower green-sands. At Elbœuf, where the ground is about 27 feet above the sea, the water rose to about 82 feet above the ground, or 109 feet above the sea. As the plain of Grenelle is 104 feet above that level, M. Mulot thought, very correctly, that if he reached the same sheet, the water would necessarily flow over the surface. MM. Arago and Walferdin, who brought to M. Mulot's assistance the influence of their scientific knowledge and their great reputation, found in the course of their examination of the district that the level of the green-sands at Lusigny, 12 miles above Troyes, where the Seine leaves those formations, was nearly 300 feet above that of the plain of Grenelle. The inference they drew from this fact was, that the water would not only overflow the bore-hole, but also rise to a very considerable height above the ground.

Upon these reasonings M. Mulot commenced his work; and after eight years of indefatigable labour, in spite of all the accidents of the undertaking and the sneers of the incredulous, on the 26th of February, 1841, his perseverance was crowned with the most signal success. The depth attained at the period of reaching water was not less than 1 802 feet from the surface, or about 1 698 feet below the level of the sea. The strata traversed were as follows:—

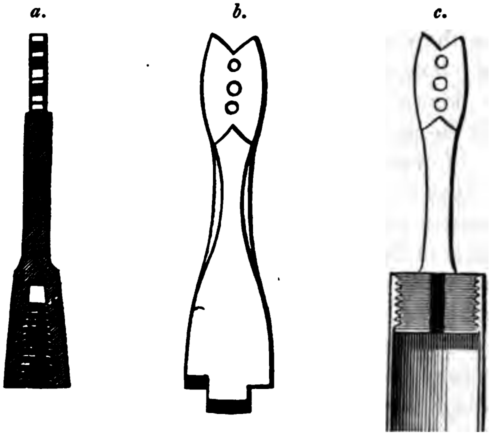
Drift gravel, about	33 feet.
Sand, clays, lignites, &c., replacing the calcaire grossier	100 „
Fragments of chalk in a species of clay	16½ „
Chalk	1 378 „
Chalk marl	88½ „
Gault clay and green-sands	186 „
Total . . .	1 802 feet.

When the water rose to the surface, it was ascertained to be of a temperature of 81°·81 Fahrenheit; and it remains of that degree to the present day. M. Walferdin, who watched the progress of the work with great interest, made a series of observations to ascertain the law of increase of temperature at great depths. He found that at Paris the thermometer remained constantly at 53°·06 Fahrenheit in the cellars of the Observatory, which are 94 feet below the surface: in the chalk, at 1 319 feet from the surface, it marked 76°·3; in the gault, at 1 657 feet, it marked 79°·61; thus showing that in the depth of 1 553 feet the increase of temperature was 26°·55, or about 1°·7 Fahrenheit for every succeeding hundred feet beyond the depth of constant temperature. According to this law, the temperature at the depth of 1 802 feet from the surface ought to have been 81°·96 nearly; and that of the waters, stated above to be 81°·81, is a striking illustration of the beauty and correctness of the inductive reasoning followed by M. Walferdin.

Amongst the numerous difficulties attending a work of this kind, those arising from the rupture or fall of the boring-tools were the most dangerous. Thus, when a depth of 1 250 feet had been reached, a length of about 270 feet of the rods fell to the bottom, and broke into several pieces. It required all the ingenuity of M. Mulot, and not less than 15 months' labour, to remove the fragments, one by one, by the aid of a screw-tap, which was made to fit upon the ends of the rods. In April, 1840, a

chisel fell to the bottom, and buried itself in the solid chalk. In this case it became necessary to clear away all round the tool, and to raise it by the same means as before. About three months before the water-bearing stratum was reached, a shell also fell to the bottom: M. Mulot pushed this aside, and continued the boring beyond it.

Drawings of some of the tools used by M. Mulot are added.



a, is the screw-tap contrived for raising the fragments of the rods from the bore.
b, a chisel, similar to the one which fell to the bottom.
c, a screwed plug, fitting into the tubes, by which these are lowered to their positions.

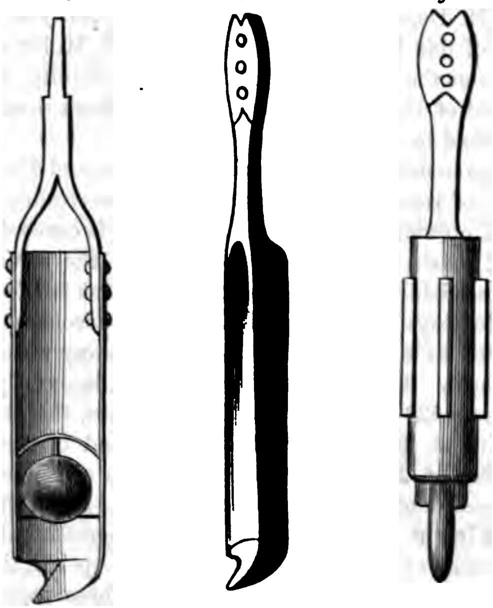
The quantity of water supplied by this well is about 800 000 gallons per day, rising to a height of 122 feet above the ground. The total cost was about 400 000 francs. It is to be observed that even now the rising pipes are occasionally choked with the sand from below.

Artesian Wells in the Valley of the Loire, near Tours.

M. Degousée mentions that he has executed no less than sixteen borings of this description in the department of the

Indre et Loire, of which ten are in Tours itself and six in the neighbourhood; their average depth is about 150 mètres, or 500 feet. Only two of these borings were unsuccessful, viz., that of Ferrières Larçon, and that of Evres, situated in the neighbourhood of the outcrop of the cretaceous formations, upon the Jurassic limestone of the

d. e. f.



d, a scoop, with ball clack, for removing wet sand.
e, an ordinary shell.
f, an auger for enlarging the bore to place tubes.

province of Poitou. All the others furnish a copious supply, and, with the exception of that of Marmontier, the water flows over the surface. The waters of these wells are employed for many industrial purposes, amongst which the most interesting are their adaptation to mills and irri-

gation. The cost of these wells was upon the average about £1 per foot lineal of descent.

The well at the abattoir of Tours passes through the lower tertiary formations and the alluvions of the valley of the Loire. The water rises from the green-sands, below the chalk, which immediately succeeds the tertiaries; and the total depth of the boring is 146 mètres, or about 478 feet. M. Degousée mentions that subsequently to the execution of this boring under his orders, M. Mulot executed another at the hospital in the immediate vicinity, and that the yield of the well of the abattoir has been considerably diminished in consequence.

The non-success of the borings at Evres and Ferrières is worthy of remark, as illustrating the uncertainty of this class of operations. At Evres, the chalk is covered by 395 feet of marls, sands, and sandstones of the tertiary formations, yielding water. The chalk is about 167 feet thick, and the clays and sands of the subcretaceous series are traversed to a depth of 66 feet without any water rising from them. The total depth of this well is exactly 191·66 mètres, or 628 feet 6 inches. At Ferrières, the chalk was met with at 30 feet from the surface, and traversed in a thickness of 219 feet. The boring was continued to an additional depth of 235 feet, or about 454 feet from the surface in the clays and sands of the subcretaceous formations, and was continued about 30 feet deeper in the marls of the Jura limestone series. As both these positions are favourably placed with respect to the level of the river Creuse, which is supposed to feed the Artesian wells in the Touraine, the only explanation of their unsuccess must be found in the existence of some fault by which the flow of the subterranean sheet of water is intercepted.

Well near Calais (Department of the Pas de Calais).

This well is another instance of the uncertain results to be met with in the prosecution of deep borings. The bore was

continued through the chalk, and the whole range of the subcretaceous formations, into the transition rocks immediately underlying the green-sands; but no water was met with,—under serviceable conditions at least. Mr. Prestwich gives the thickness of the strata traversed as follows:—

	Feet.
Gravel and loose wet sand	80
Clays, sand, and pebble beds	161
Chalk	762
Upper green-sand	3
Gault	24
Lower green-sand	17
Transition rocks	103
Total	1 150

In this case, also, the subterranean stream is in all probability intercepted by a fault.

Well at Chichester.

In Mr. Gatehouse's well, South Street, Chichester, the following strata were traversed:—

Strata.	Thickness of Strata.	From ground.
Vegetable mould	6 feet.	
Gravel	16½ "	22½ feet.
Red sand	½ "	23 "
Blue clays	60 "	83 "
Coloured (mottled) clays	97 "	180 "
Chalk	729 "	909 "
Chalk marl	61 "	970 "
Upper green-sand	84 "	1 054 "

The boring was stopped in October, 1844, and about 370 feet in length of the rod, and the slush-pipe attached to it, were left in the bore; nor has any subsequent attempt been made to extract them. No pipes were used in the sand.

The quantity of water yielded is very small. One of the most remarkable facts connected with this well is, that the water-line is about 18 feet from the surface of the

ground, whilst that of the wells of the same district, supplied by infiltration from the superficial gravel, is only six feet below the surface. The point where the Arun leaves the green-sand formation, a little above Chichester, is, however, at a sufficient elevation to have warranted the expectation that the water would have overflowed.

The water from this well at present is decidedly chalybeate, and has a very strong and repulsive taste and smell of sulphuretted hydrogen; its temperature is not such as to indicate that it rises from the green-sand.

Well at Southampton, on the Common.

This well was commenced upon a report made by Mr. Clark, of Tottenham, to the effect that a copious supply of water would be obtained from the chalk in the position of an experimental boring made by that contractor. The Town Council very unfairly, and, as circumstances proved, very unwisely, did not employ Mr. Clark to carry out the plan he suggested, but entered into a contract with a party in the town, who, as might have been anticipated, failed, and left the work to be completed by his sureties. The latter carried a well through the sands, clays, and mottled clays of the Hampshire tertiaries, into the chalk, to a depth of 560 feet from the surface of the ground, and about 106 feet into the chalk; a boring was then commenced, and after a period of fifteen years from the date of obtaining the Act of Parliament for these works, and a positive expense to the ratepayers of about £13 000, the work has lately been abandoned when a depth of not less than 1 317 feet had been attained. As a question of abstract science this is to be regretted; because the solution of the question of the possibility of obtaining a supply by means of Artesian wells from below the chalk is very desirable; and it might be attained in this case with comparative ease. But the arguments brought forward by Mr. Ranger appear to be sufficiently cogent to justify

the discontinuance of the experiment at the expense of the town. Public money should never be expended, in fact, unless with a certainty of attaining the end proposed; it should never be employed in carrying out theoretical views or for the attainment of what may be called hypothetical, or eventual, advantages. It is to be hoped that some scientific body, or some lovers of science, may take up this question in its present state.

The strata traversed may be briefly described as consisting of the following materials, viz.:—

A series of sands and clays, with beds of loam intercalated, which appear to represent the Bagshot sand formations of the London basin; in thickness . . .	90 feet.
Clay with lignite, shell limestone, pebbles, and sand of the tertiary formations . .	261½ ,,
Mottled clays and sands; the basement beds of the tertiaries	82½ ,,
Chalk, with flints	851 ,,
Chalk marl, as far as boring has proceeded .	12¼ ,,

These dimensions, however, are only approximations, because it is almost impossible to say that the precise limits of either the great tertiary clay, or of the chalk marl, can be clearly defined.

Recent analysis of the water of this well shows that there is present in it a very large proportion of common salt in solution. If this be found to be the normal condition, it would lead to the conclusion that there is an underground communication with the sea, although the height to which the water rises (viz., 100 feet above the latter) proves that it can only exist by infiltration through the pores of the chalk.

Artesian Well at Northam, near Southampton.

In the lower part of the town of Southampton there are four wells, supplied by the waters rising from the lower members of the tertiary series. Two of these are in the

Docks, one in the Railway Station, and one at Northam was sunk by the Town for the supply of the inhabitants.

The wells of the Docks and of the Railway Station vary from 220 to about 240 feet, and being very close together, they have produced a reaction, which has materially affected the quantity they respectively yield. The Northam well, however, is much deeper; for the bottom, still in the blue clay, is at 375 feet 6 inches from the surface, although the Dock and Railway wells derive their supplies apparently from the sands lying between the clay and the chalk. It would be fair to assume from this fact of the difference in the thickness of the strata, that the Northam well is situated upon a species of gully or depression of the chalk.

Artesian Well at the Caledonian Road, London.

The rates accepted for sinking a 6-foot shaft, were for each depth of 30 feet, thus:—1st, £67 10s.; 2nd, £57; 3rd, £58 10s.; 4th, £60 10s.; 5th, £61 10s.; 6th, £67 10s. The following were rates per foot:—For 10¼″ boring and fixing pipes, £2 2s.; for 7½″ boring in chalk, £1 7s.; for perforated copper pipes fixed, 10s. 2d.

In commencing the work five men were employed, who made an excavation 9′ 6″ diameter, which was to allow space for the finished shaft to be 6′ 0″ in the clear, with the 9-inch steining, and 12 inches of puddle at the back, for more effectually excluding the land-springs. This excavation was carried down to the depth of 10 feet. The 9-inch steining in cement and the puddle were then commenced, and completed to the surface. The stratum of clay at this depth was so solid, that it was considered that the puddle might be dispensed with; an excavation only 7 feet 6 inches in diameter, and 5 feet deep, was therefore made, and the back steining only, of half a brick in thickness, completed in cement. Similar excavations of five feet in depth were made in succession, the back steining alone

in each case being completed, until the solid mass of London blue clay was found, at the depth of 30 feet from the surface. The inner steining was then brought up in cement, so as to underpin the first portion which had been completed. The land-springs were found to be effectually excluded, and the work then proceeded in all respects according to the specification. Two additional hands were employed when the well was about 30 feet deep, and no difficulty was experienced until the mass of London clay was cut through, and the upper beds of the plastic clay formation, which were found at the depth of 150 feet, were perforated. Here a stratum of dark sand was found, containing a little water. This sand was so loose that it did not afford sufficient foundation for the brickwork; and there was this further difficulty, that had the water been pumped out, the sand would have been set in motion, or, to use a technical expression, would have blown up in the well. Under these circumstances, it was determined to substitute cast-iron cylinders, five feet diameter and one inch thick, for the brick steining.

The specification and tender for supplying the cylinders, and executing the work with them, was as follows.

Tender for supplying cast-iron cylinders to be used in lieu of steining.

Tottenham.

I hereby engage to secure the present brickwork in its place by strong elm ribs, suspended by iron rods up the shaft, and to provide and fix cast-iron cylinders of five feet diameter and one inch thick, in five-feet lengths, with internal flanges, properly packed and bolted together, and to caulk the same with iron cement, and to carry them down through the upper sand, and drive the lower end firmly into the clay; and to concrete behind the upper cylinder with gravel and cement, to form a footing for the lower steining, and for stopping out water, providing every material required for the work, at £7 2s. per foot lineal.

(Signed) THOS. CLARK.

Before proceeding to lower the well or fix the cylinders, it was necessary to secure or tie up the brickwork which had been already executed. For this purpose a strong elm frame was inserted under it, and the frame being connected by 1¼-inch rods, with two strong beams fixed over the top of the well, effectually secured the steining in its place. In order to steady the cylinders, and keep them in a right line as the work proceeded, four battens, 20 feet long, 7 inches wide, and 2½ inches thick, were fixed to the lower part of the brickwork, forming a kind of frame through which the cylinders would slide; this being arranged, the first cylinder, 5 feet in length, was lowered to the bottom, and, after being properly adjusted by means of wedges, another was added on the top, and the joint of the flanges made good; four others were added in succession, making a length of 30 feet of cylinders fixed, before the excavation was proceeded with. The object of this was twofold; first, that the outer surface of the cylinders being confined within the wooden frame already described, the true direction would be maintained; and, secondly, that the weight of the mass would aid in its descending into its place as the boring or excavation was proceeded with: by these means, had the stratum proved to be a quicksand, the difficulty would have been overcome: a stage was then placed on the upper part of the cylinders, and an auger, 4′ 10″ in diameter, was introduced within them. Each time that this auger was drawn out, the cylinders settled on an average about two inches, and no difficulty was experienced. The stratum of sand, which was about 20 feet in depth, was cut through, and a hard mottled clay was found under it: it was essential that the cylinders should be firmly fixed in the clay, in order to prevent the water contained in the sand from forcing its way under them, and rising into the well. The boring was therefore continued for a few feet, and the cylinders were at last driven into the clay with a heavy dolly, made

of the rough trunk of a tree. The water, which had hitherto stood above the level of the top of the sand in the cylinders, was now pumped out, and the well remaining perfectly dry, afforded evidence that the water contained in the sand had been effectually stopped out. The 12-inch pipe mentioned in the original specification was dispensed with, and the boring was continued with a 10½-inch auger down to the chalk; 8-inch pipes were then introduced, which were firmly fixed several feet into the chalk, and were left standing 6 feet above the bottom of the cylinders. The object of this latter arrangement was, that any sediment contained in the water might settle at the bottom of the well.

The following is a section of this well, together with the distance from the surface of the ground to various points in the well itself :—

	Feet.
Yellow clay and gravel	30
Blue clay	100
Mottled clay	19½
Dark loamy sand, and little water	18
Hard mottled clay and sand, without water	17
Dark sand, with little water	34
Hard flint	1
Chalk	151
Total depth	370½

	Feet.
Distance of bottom of brick shaft to surface	153
,, from top of iron cylinders to do.	139
,, from bottom of iron cylinders to do.	170
,, from bottom of iron piping to do.	230
,, from top of copper piping to do.	220
,, from bottom of copper piping to do.	259

On the completion of this well, it was considered desirable to test the strength of the spring by pumping, which operation had also the effect of freeing the sides of the bore, thereby allowing the water to percolate more quickly, as

the action of the tools necessarily had a tendency to harden the chalk. The pump was kept at work night and day, a relieving gang of men coming on every four hours. After working in this manner for 48 hours, the level of the water in the cylinders was marked, and it was also ascertained that in one hour rather more than 900 gallons were removed from the well. The water-level was lowered by the pumping one foot; and as a hole five feet in diameter and one foot deep contains 122 gallons, that amount deducted from 900, gives as the water-supply nearly 800 gallons per hour.

Artesian Well at Bulphan Fen.

The description of the following example is considered well worthy of remark, as it tends to show the great advantage arising from a plentiful supply of water, together with the ease with which it is often obtained in districts apparently wanting in that necessary article.

At Bulphan Fen, within a few miles of Aveley, Essex, is a large tract of grass-land, situated at a low level, and liable to be much flooded in the winter season. Its value was formerly little, as in the summer time it was destitute of good water, being wholly dependent upon the pools and ditches which retained the remains of the winter's rain and floods. This rendered it unfit for stock, as, in addition to the small quantity of water remaining, even that was rendered bad by the heat of the weather. The landowners in the neighbourhood were induced to bore, and, being successful in finding springs, the water from which overflowed the surface of the ground, their example was followed by the proprietor of the Artesian well under consideration, who, together with his father, suffered much inconvenience from the scarcity of water upon 300 acres of low grass-land at Aveley. A spot was fixed upon at the edge of the uplands, and about the level of high-water mark of the Thames: during the month of August, 1835, the work was

commenced. The bore of the auger was 3 inches. The first 5 or 6 feet were an alluvial soil, mixed with many small stones, the whole of a gravelly nature; succeeding this was a very soft, boggy ground, which ran in as fast as bored out; into it were inserted wrought-iron pipes of the usual construction: the thickness of this bog was about 2 feet. The next substance was light brown sand, very close, firm, sharp, and fine; it became darker as the work proceeded, till, at 65 feet from the surface, it was almost black. Separating this sand and the chalk, was a small portion of light, grass-green, flaky rock. In the chalk were layers of flints; and the boring was carried on in this formation about 35 feet, when the auger and rods suddenly dropped seven feet into a cavity of very soft, almost liquid chalk, from which the water rose to within one foot of the surface of the marsh; water had been met with previously, but not in such large quantities as this spring furnished; and, no doubt, the water from this would have risen higher but for its connection with other and weaker springs, which reduced its standing level by abstracting a portion of the water instead of adding thereto, notwithstanding the greater hydrostatic pressure exercised upon the lower and stronger spring: it must, therefore, always be borne in mind, that where a great rise of water is wished for from a deep strong spring, all others should be very carefully blocked out; when quantity, and not standing level, is the question, the conditions of the case are altered. To return from this digression: the water in this well, which, as before remarked, rose almost to the surface, was conducted by a 2-inch pipe, inserted 3 inches under the water-level, into ditches traversing the land; the water ran white for some days, but ultimately perfectly clear, and continues to run night and day. The temperature is 51° Fahr. winter and summer, and the quantity delivered in 24 hours about 30,000 gallons; it supplies 2 miles of ditches 10 feet wide, from which it runs into the sea.

In the neighbourhood of the above Artesian bore are situated some wells of the ordinary kind; the spring or springs to which they are sunk are strong, the water rising to the same level as in the Artesian one; they receive their supply from the saturated sand spoken of above, and which is situated upon the top of the chalk. The identity of level between the wells is, no doubt, owing to their communication, which is established by the water from the chalk rising outside the pipe which lines the bore, the water naturally preferring such an exit to rising higher inside the pipe itself. Even with the most carefully executed work, it is difficult to prevent water rising outside the boring-pipes where they pass through sand; therefore, in ordinary cases, such an effect may be expected to take place, unless the lower springs are separated from the upper by an impermeable collar of clay or other matter through which the pipe passes.

CHAPTER VII.

NOTES ON DEEP ARTESIAN WELLS MADE AFTER 1851.

SINCE 1851 the operations of Local Boards of Health, of the Paris Municipality, and of numerous private parties, have enabled the engineer to reason more definitely upon the conditions of the supply of water to deep-seated wells; but this has been accompanied with a corresponding amount of uncertainty in the operations undertaken for the purpose of procuring water from them, that leaves the whole subject involved in mystery when the strata traversed are so traversed for the first time. The fact seems to be, that in the matter of the geological constitution of the earth, science can tell us what we *shall not* meet with; it can never tell us what we *shall find*. The *order* of strata is never reversed, except in well-defined

cases of volcanic origin; but it by no means follows that this order has everywhere been followed, or that the sequence of the strata has been invariably observed over large extents of country, with sufficient regularity to enable any one to count upon their yielding the results that are expected to flow from them. It consequently follows that the first operations that are undertaken in the hopes of discovering a deep-seated spring, such an one as would furnish an Artesian well, are always attended with considerable risk of failure; but that, if they once succeed, the conditions of the quantity so supplied, and the height to which it will rise, can be with certainty predicted. Illustrations of both these laws will be given in the notices of the wells hereinafter described, and the geological inferences to be drawn from them will be occasionally noticed.

Deep Well at Hampstead.

The first well that claims our attention was the one that had been executed for the Hampstead Water Works Company, in order to comply with the provisions of the Metropolis Water Works Act of 1851. In this case, the directors were obliged to seek for a supply that was independent of any natural watercourse; and after consulting Mr. Prestwich, the greatest authority we have upon hydrographical geology, they determined to seek through the chalk, in the hope of obtaining a supply from the lower green-sands that were known to crop out on the edges of the chalk basin, like the Paris strata did, and that were supposed to be continuous under the chalk. The boring was confided to Messrs. Degoupée and Laurent, who had great experience in this class of work, and had executed some of the most successful wells upon the Continent. The shaft had been already sunk through the London clay, and the chalk, to the depth of 530 feet from the surface, at which level the boring commenced, at first with a diameter

of 12 inches, subsequently reduced to 10, and finally leaving off with a diameter of 8 inches. The chalk was found of its calculated thickness; the upper green-sand and the gault were found to be as they were expected; but at the depth of 1 113 feet from the surface, the boring tool passed into a succession of beds, consisting of alternate layers of red sandstones, red clays, conglomerates, and sands, which geologists were disposed to believe were members of the new red sandstone series, instead of the lower green-sand that they expected to meet with in this position. The consequence of this was that the boring was stopped, at a further total depth of 1 302 feet from the surface; and the Company was ruined.

Deep Well at Harwich.

About the same time, Mr. Peter Bruff was engaged upon the attempt to obtain a supply of water for the town of Harwich (which is situated upon the outer, or seaward edge of the London clay), by means of an Artesian well, in consequence of the success of Mr. Lancaster Webb in his search for water by the same means at Stowmarket, which is situated upon the chalk, higher up the valley of the Gipping, an affluent of the Orwell, that falls into the sea at Harwich. Attempts had been previously made to sink wells in this spot, but they had always proved unsuccessful, in consequence of the communication of salt water with the land waters, in the operations carried on near the sea-shore; and therefore the local authorities determined to try whether they would be more successful in the attempt to obtain a supply from a deep-seated source, such as would be furnished by the lower green-sands, which analogy indicated would be found under the chalk basin of the London clay. In the case of Mr. Lancaster Webb's well, that gentleman had sunk through the superficial gravels and clay, through the chalk forma-

tion, the upper green-sands, the gault, and he obtained his supply from the lower green-sand, at the depth of 895 feet from the surface; but there was, of course, a considerable difference of level between the position of this well from that undertaken at Harwich. It happened, however, that in sinking the latter well, the men employed found that after they had sunk through the London clay, the chalk, the upper green-sand, and the gault, the boring passed at once into a slaty rock of a black colour, which Mr. Prestwich pronounced to be a member of the Cumbrian or Westmoreland slates, although its precise situation in the series could hardly be ascertained, in consequence of the absence of fossils in the materials obtained from the boring. This strange result was a confirmation of the observations recorded to have been made at Calais, where a member of the pre-carboniferous series was found to exist under the gault, and it to a great extent confirmed the opinion that the whole of the series of strata between the new red sandstone and the gault were absent under London, as in the boring at Highgate Hill. Similar results have also been obtained at the well that has been sunk for the town of Ostend, which is situated in the prolongation of the London tertiaries upon the Continent.

Deep Well at Passy.

The Paris Municipality has lately been induced to repeat the successful operation that they had accomplished at Grenelle, by sinking a well at Passy. They confided the execution of the works in this case to M. Kind, who had executed some of the deepest wells that had been executed in the Rhenish provinces of Prussia and the neighbouring countries, for the purpose of extracting salt from the brine springs that rose from the marls of the new red sandstones, and who had established a reputation for the manner in which he had succeeded in sinking the shafts of certain coal-mines through the running sands that are often met

with in the coal measures. The first intention of the engineers of the city was to execute the boring of the same diameter as the Grenelle well, that is to say, of 8 inches; but M. Kind undertook to terminate the boring of the diameter of 2 feet, and he also contracted to deliver the water at the height of 92 feet above the level of the ground, at the rate of three million gallons per day. This he engaged to effect within the space of two years, and to complete the works for the total sum of £14 000. There were, of course, many opponents of M. Kind, on the score of his nationality, and on the score of the increased delivery that was presumed to be attained over the well of Grenelle; but at last the authorities were persuaded to allow M. Kind to go to work, with the processes he introduced. This took place in consequence of the vote of the Municipal Council on the 23rd of December, 1854. The works were commenced shortly afterwards, and by the 31st of May, 1857, the boring had already been carried to the depth of 1 732 feet from the surface, when suddenly the upper portion of the lining of the well collapsed, at the distance of about 100 feet from the ground, and choked up the whole of the boring. This accident led to the failure of M. Kind, and considerably delayed the progress of the works; but the Municipal Engineers were so satisfied with the energy and skill that M. Kind had displayed in the conduct of the works, that they entrusted the conduct of the remaining operations to him upon the resiliation of his original contract. A well was sunk, and lined with masonry, to the depth of 175 feet 4 inches from the surface, and the boring was then cleared out and resumed. Much trouble was encountered in traversing the strata that were situated below the distance of 1 732 feet from the ground, above quoted; and at length, at about 1 894 feet from the surface, the first water-bearing stratum was met with; but the water, after several oscillations, did not reach the ground. The boring was continued below this

level, until on the 24th September, 1861, at mid-day, the true Artesian spring was tapped, at the depth of 1 928 feet 8 inches from the surface. When this spring first rose, it discharged about 5 582 000 gallons per day, but the yield of the well in its normal state has oscillated considerably. So long as the column was not raised above the level of the ground, however, the total quantity delivered did not vary much from that of 4 465 600 gallons per day. It had been noticed previously that the well of Grenelle had sunk gradually, in consequence, no doubt, of the obstruction of the tubes in it, until the rate of delivery had reached 200 000 gallons a day, instead of 800 000 gallons that it had originally yielded: but it was also observed that the Grenelle well was affected within 30 hours after the Passy well had been continued to the water-bearing stratum, until the yield of the former had settled to the rate of 173 000 gallons in the day of 24 hours. The delivery of the Grenelle well remained stationary at the above rate, so long as the height to which the water was delivered at Passy remained the same as it was originally; but when this was altered so as to make the points of discharge of the two wells equal in height, the yield of the Grenelle well was resumed, and the yield of that of Passy fell off until it only amounted to 2 000 000 gallons per day. The horizontal distance from the Passy to the Grenelle well is about 3 830 yards, and the depth of the water-bearing stratum is, at Grenelle, 100 feet nearer the mean level of the sea than it is at Passy; while the surface of the ground is about 35 feet higher in the latter locality than it is at Grenelle.

Without doubt the effect produced upon the respective sources of supply, by the alterations in the heights of the columns of water delivered, proves that both the Passy and Grenelle wells are fed from the same water-bearing stratum; nor can there be any reason to doubt but that the Passy well water would be of nearly the same composition

as that of Grenelle, when once the passages through which the water flowed were cleared from accidental impurity. M. Pelligot has carefully analyzed the Grenelle waters, and he found that they contained 0·000142 of saline matters, composed principally of the carbonate of lime, potash, and magnesia, associated with a compound of sulphur and soda, of variable proportions and conditions, and with the carbonate of the protoxide of iron and silica. The salts of the sulphide of lime, that are amongst the most permanent impurities of water, are entirely wanting; and it would appear that the gases diffused through the water are of considerable volume, the carbonic acid gas being the most so. There is a sensible evolution of sulphuretted hydrogen from both the well waters of Passy and of Grenelle; and it is worthy of remark that the same gas is given off from the waters obtained by Mr. Gatehouse, of Chichester, though, in this case, the quantity of gas is sufficient to render the water quite unfitted for drinking purposes, which is not the case with the waters at Passy or Grenelle. The temperature of both these sources of supply is about 82° Fahrenheit, which is another proof of their common origin; the Grenelle well, as was said in the text, rising at nearly that degree of temperature. Unfortunately, the tubing that M. Kind introduced in the progress of the work has proved to be utterly untrustworthy, and the consequence has been that the water from the bottom of the boring has communicated with the various water-bearing strata that it encounters in its ascent, thus increasing both the volume and the temperature of the latter, and furnishing a nearer outflow for the waters that it yields than is provided for it upon the surface. Practically, the results of the Passy well are, for the present, without any result; though the cause of this is well known, and can be remedied by simply lining the bore with impermeable pipes.

It may be worth while here to call attention to the

mechanical means adopted by M. Kind in sinking a boring of the large diameter of 8 feet 4 inches, which size was adopted in the well at Passy, to the enormous depth of nearly 2 000 feet from the surface of the ground. The work was commenced with a shaft, as is usually the case, and after it had been sunk to the depth of 50 feet in the original well, the boring commenced, and was continued with, as nearly as possible, the same diameter to the bottom. M. Kind employed for the purpose of cutting through the strata what may be called *rods with releasing joints*, very closely resembling the joints already described as invented by Œuyenhausen, which allowed the cutting tool to be raised a certain height, and then to be released automatically. This arrangement was adopted in order to avoid the lashing of the sides of the boring by the long rods, and to regulate the force of the blow of the cutting tool. This tool likewise differed from the tools generally employed, for it consisted of a single or double trepan, according to the nature of the ground, instead of the ordinary chisels and augers. A patent was taken out for these tools in the year 1854, under the number 13 478 of the English patents, the printed specification of which contains a series of engravings of the various modifications of the tools proposed for the different kinds of works; and in the *Annuaire Scientifique* for 1861 there will be found an illustration of the trepan used by M. Kind, and of the slide joints. The patent of 1854 specifies also certain methods of lining the boring; but it must be confessed that they do not appear to have been successful, for M. Kind encountered greater difficulties from the collapsing of the tubes than from any other cause. It is a common error with well-borers to undervalue the effort exercised by clays swelling when charged with water, and the great delays that arose in the case of the Passy well were precisely attributable to this cause, which partly arose from the false economy attempted to be introduced into the

means of tubing the bore. The time actually employed in sinking the well of Passy was very nearly the same as that which had been employed upon the well of Grenelle; the former took six years and seventy-five days, the latter seven years and ninety days; but it was the first attempt at sinking to such a depth and in such a strata. The cost of the Grenelle well was £14 000, that of Passy was £40 000; but it must be observed that the quantity of water, delivered at the same height in the two cases, was, as long as the tubes of the well of Passy continued in working order, ten times greater than that at Grenelle. This thing was, at any rate, proved by the temporary results of the experiment of Passy, viz., that the ratio of delivery was in the direct ratio of the diameter of the boring. M. Kind, it may be as well to add, was enabled, by the use of the tools that he employed, to strike as many as twenty blows per minute, at a depth of 2 000 feet, with the greatest regularity.

In a lecture delivered by Mr. Burnell, before 1861, he pointed out that observations should be made upon the yield of the Artesian wells of Elbœuf and Rouen, that are fed from the same beds of the lower green-sands that are resorted to in the wells of Grenelle and Passy, in order to be able to ascertain whether the yield of the water-bearing stratum would be affected. In the present state of the well of Passy of course this would be a matter of little interest, but the necessity of observing closely the effect of two or more such wells upon the probable supply is evident from the results obtained in the neighbourhood of Tours, where the wells were so numerous that they had mutually affected one another. The same thing has also been observed in London, where the Artesian wells from the Woolwich sands and the sands of the plastic clay series have ceased to flow over the surface in the great majority of cases; and the level of the water in the chalk *is gradually* declining in consequence of the great draft

that is made upon that source of supply. In Paris it is the more necessary to ascertain the effect of the Artesian wells that are about to be sunk in that basin, because the city is about to sink a series of them for the improvement of its water supply; indeed it has already begun the execution of two of them. It cannot be too much insisted upon that observations are needed upon the effect of these wells upon the yield of those already established, as there is no law by which the right to the supply in this case can be protected, and the first person who would establish a well in a more favourable position than the city of Paris might render all the outlay that the latter might encounter vain.

Wells in the African Sahara.

The French Government have lately made experiments upon well-boring on a very large scale in the Desert of Sahara, and they have thus been enabled to diffuse the blessings of civilization in those inhospitable regions. These experiments were executed by means of tools invented by MM. Degousée and Laurent, who seem also to have acted as consulting engineers to the officers of the *Génie Militaire* who were specially charged with the direction of these operations. It appears that up to the month of June, 1860, no less than 50 of these wells had been sunk in the desert, and that they pour upon its thirsty soil no less than 7 920 000 gallons of water per day, giving rise to the formation of numerous oases, for the effect of water upon vegetation is marvellous in those climates, although the quality of the supply is, in these cases, very far from being of an irreproachable nature: the waters are brackish, and they contain many salts of magnesia. It is to be suspected that, notwithstanding this defect, which is partly owing to the fact of the water being furnished from the bed of a former sea basin, that much of the difficulty which is found in traversing the great deserts of Central Asia and Australia might be thus obviated, and the French Govern-

ment has conferred in this matter a service on all humanity in facilitating the means of intercommunication.

Unsuccessful Wells at Hastings, Rugby, and Middlesborough.

The risks and uncertainty that attend the first essays towards the attainment of a water supply in an untried formation are strikingly illustrated by the results of the borings of the Hastings, the Rugby, and the Middlesborough wells. In the Hastings well, after traversing about 600 feet through the Wealden beds, the operations were suspended, when the well-borers were upon the point of discovering whether the Wealden series reposed upon the upper Portland beds, or whether they reposed upon the carboniferous series, as they are known to do in Belgium. Of course every attempt to solve this question must be involved in great doubt, because it is impossible to predicate the thickness of the strata that would be met with. It may be that the Wealden formations at Hastings are 700 feet, or they may, with equal probability, be of 1 700 feet in thickness. But the interest that attaches itself to the question of the occurrence of coal in this part of England is so great that it may nowadays, when Sir W. Armstrong has called attention so forcibly to the limited duration of our supply of that means of power, be considered a subject of regret that this well should be abandoned. In the case of the Rugby well, the operation of boring was resorted to with the hopes of meeting with a supply of water from the new sandstone, which the Engineer counted upon finding after having traversed the beds of the basement of the blue lias formation. At Liverpool and Birkenhead the well-boring operations had been remarkably successful in the triassic group of the new red sandstone, which were also considered to continue under Rugby; but the result of the experiment has been that, *after traversing* the lias and the new red sandstones, to

about the depth of 1 200 feet, the well-borers only found that they had attained the brackish waters that are usually associated with the saliferous marls of the latter formation. The Middlesborough well was, if possible, marked with more decided results than the Rugby one, in this respect that it brought to the surface a more powerful brine spring, that is capable of being worked for the extraction of salt, whereas it was sunk with the expectation of meeting with a supply of pure and fresh water. It was, however, entirely sunk in the new red sandstone, and was principally interesting, in that it proved the risk that was run in the course of well-boring in these formations, from the very variable nature of the constitution of the new red sandstone.

Deep Well at Brighton.

The success of the Board of Guardians of Brighton in their attempt to attain a supply by means of an Artesian boring at their establishment at Warren Farm, a little to the north-east of the town, is the most singular of the results that have lately been obtained. In this case the well was sunk through the chalk, the upper green-sand, the gault, and the water supply came from the lower green-sand, at about the distance of 1 300 feet from the surface; but there have been no observations recorded upon the height to which the waters rise in this well, nor have any experiments been yet made upon the temperature of the waters so delivered. The well itself was sunk in the teeth of common sense, inasmuch as it was made with a break in about the middle, that certainly would oppose the renewal of the air in the bottom of the excavation, which was carried on by the old methods of sinking. But the results were the same, and the facts proved by the success of this well are that there are apparently proofs of the existence of the continuous chalk basin and the subjacent series under the Hampshire basin, and apparently under the

British Channel, thus showing that there existed in this instance a difference in the conditions of deposition of the North and South Downs, so far as the strata of the rocks that were under them were concerned. The results of this boring were also to a great extent a condemnation of the conduct of Mr. Gatehouse, of Chichester, and of the Local Board of Health of Southampton, in abandoning their wells at the depth that they had attained; but the Warren Farm well has not yet proved so successful as to warrant any one in the assertion that they had been moved by any but prudential motives in their conduct on this occasion. The depth that was reached at Southampton was in itself enough to create the belief in the existence of conditions of the subjacent strata that might lead to very different results in that particular case. It is to be observed that in speaking of this well as an *Artesian* well, there is a slight confusion of terms, inasmuch as the water does not flow over the surface, but is raised by a force pump; but the means by which the supply is obtained is sufficiently like that adoped in the ancient province of Artois to allow of this extension of terms.

Results in the Subcretaceous Formations around London.

There have been several wells sunk of late, with the hope of obtaining a supply of water from the subcretaceous formations, which have hitherto been without success; at least without any known results that should warrant the belief that on the edge of the London clay basin the operations connected with them should be otherwise than unsatisfactory. It is not so, however, with the wells that have been sunk in the chalk formations around London, for in many cases the well-sinkers have succeeded in raising such volumes of water from these formations as to go far towards proving Mr. Homersham's theory of the water-bearing capacity of the chalk. Thus at the well that was sunk for the late Plumstead Water-Works Company, under

the orders of Mr. Homersham himself, a good supply was met with, at some distance from the surface it is true; but at the Kent Water-Works the most remarkable of these operations have been carried on and the most extraordinary results obtained. In this case the wells have been sunk in the Ravensbourne valley that gives rise to a feeder of the Thames, and is situated with a main direction from south to north. The valley is upon a line of upheaval of the lower tertiaries, which are here brought to the surface by a movement of the chalk formation that is continued through the course of the Thames, and displays itself in the valley of the Lea on the north side of that river. It would appear that the line of the chalk springs has, under these circumstances, been interrupted, and the waters from them have previously found their way to the sea through some of the innumerable fissures of the chalk formation; but when a vent was found for them at a point more favourable for their discharge, as was done in the borings of the Kent Water-Works Company, they began to flow with great abundance. The springs that were tapped on this occasion rose from about the distance of 316 feet from the surface, and they were under sufficient pressure to cause them to rise to the height of several feet above that level, with a daily discharge of about eight million gallons in the total number of the borings, a quantity sufficient to the supply of the great part of the consumers of this company. Nor has this been the only one of the wells that have been lately sunk in the chalk. The Hanwell Lunatic Asylum has resorted to this source; the Government have in the wells at Trafalgar Square and in Hyde Park availed themselves of it, in the former case going down to 320 feet deep, and in the latter to 341 feet; and numerous Local Boards of Health have been induced to try this means of obtaining water. The Braintree Local Board has thus sunk a boring to a distance of 348 feet from the surface, which is supplied from the chalk formation at a distance of 120 feet from the

point where it is entered; but there is this peculiarity about the yield of the spring that supplies the well of this town, that in the valley of a small stream that runs into the course of the river of Braintree, below that town, the chalk has been found to yield a most copious supply at the depth from the surface of 244 feet, and this, too, with sufficient ascentional force to cause the water to flow over the surface. The results that have been obtained by the Water Company at Grays may be likewise appealed to in confirmation of the water-bearing capacities of the chalk formation in the neighbourhood of London at any rate. The importance of this consideration is becoming every day of greater weight, when the opinion of many eminent engineers is that the population of the Thames valley is trenching so fast upon the water supply from that source, that they positively recommend the formation of large impounding reservoirs for the purpose of storing the winter's rain for distribution in the summer months. In fact, the valleys of the Cray, the Darent, and all the streams that flow into the Thames on the right bank and on the left, are at present untouched, so far as regards their water-bearing capacities; nor can there be any doubt that they could yield a quantity of water that would suffice, both in quantity and in quality, for any future increase of the population of London or its environs. The latter consideration, viz., that of quality, is at present very important, because the same engineers who have proposed to resort to the formation of large artificial reservoirs also attack the chalk waters on account of their excessive hardness. It is true that when extracted directly from the chalk the quantity of the bicarbonate of lime that is held in solution in the waters is very objectionable for the purposes of washing and tea-making, &c.; but the objectionable quantity of this salt in suspension is very early parted with by a simple exposure to the weather, and for all the other usages to which water is applied there can be no doubt of the advantages of a supply

of pure chalk water. The reader will find the properties to be desired in a town supply discussed in the "Treatise upon Hydraulic Engineering" in this series, to which he is referred.

General Remarks on Deep Artesian Wells.

A great deal of interest has been lately attracted to the operations of the well-borers in the United States and Canada, who have been eminently successful in their search for the oil-springs that so singularly mark that country. The wells that have been sunk there before 1861, in the majority of cases, however, were not very deep, nor do they illustrate any new principle in the theory or practice of this art, for the depth of the wells is about 300 feet at a maximum, and they are entirely sunk through the surface strata of the country. Much greater interest attaches itself to the research of the brine springs that is carried on with great spirit in Germany, where the depths there attained are positively frightful, as much as 2 600 feet having been reached in some cases, with successful results, it may be added. Again, however, this depth proves nothing new, either geologically or practically, as far as well-boring is concerned; and the operations of the well-borers are principally worthy of attention on account of the mechanical means they have adopted to sink through the rocks that they meet with at such depths. The great lesson to be learned from the recent attempts at well-sinking is, however, that the first operations of this kind are always attended with a considerable amount of uncertainty and risk, and that, afterwards, the quantity of water that may be attained is very liable to be trenched upon by the operations of the neighbouring landowners. Under these circumstances it certainly seems that recourse should not be had to the means of supply furnished by deep-seated wells until all other means had been exhausted, especially when, as in the case of Local Boards of Health, the money that is laid

out upon these means is obtained from the forced contributions of the inhabitants. This consideration was, indeed, the one that principally weighed with Mr. Ranger when he advised the town of Southampton to abandon their Artesian well when they were so near, as it proves, attaining success, but when the results of their operation were still involved in doubt, and it was impossible to say with certainty whether they would eventually obtain a supply from that source or not.

Again, the author repeats that the results of the deep-seated wells that have been sunk under London lend additional interest to the theory of those who hold that city to be built either upon, or near the carboniferous strata; and that from every appearance there is great probability of the occurrence of coal somewhere under the anticlinal line of the Wealden formations. In Belgium, the coal measures are situated immediately under these deposits, and the similarity of the results attained on both sides of the Channel, in the wells of Calais, Ostend, Harwich, and Kentish Town, is at any rate remarkable, when taken in conjunction with the continuance of the line of upheaval of the strata through the Weald valley, the South Downs, and on through the country to the appearance of the coal in Somersetshire, South Wales, and Ireland. It were much to be desired that this question of the occurrence of coal could be settled by some deep boring carried down to the lower strata. The operation would be one attended with great uncertainty as to the results; it would, on the other hand, be certain to involve a considerable cost, and therefore it is that we can hardly expect that it should be undertaken at the expense of a single individual, particularly as, by the state of the law, he would have no right to the benefit he might confer upon the community; or, at any rate, he would have no right to look for any advantage for the outlay that he might undertake in thus ascertaining the internal composition of the strata of the globe, as every-

body is entitled to make use of the observations that he might have pursued. The state of the law with respect to the discoveries of mining and Artesian wells is, in fact, very discouraging to the enterprise that might seek some interest in this manner. There is nothing to prevent any neighbouring proprietor from taking advantage of the outlay of capital that may be made in first sinking a well through the strata of a district to the underground sources of supply, although he may not have incurred any expense in the preliminary studies necessary to ascertain the existence of the latter. There ought to be something like a patent right to ensure the rights of those who incur the risk and anxiety of thus ascertaining the existence of the supply from the untried sources. It is singular that this state of *lawlessness* prevails in almost every country that the author is acquainted with, and the discoverer of an Artesian source is alike without any claim to the monopoly of his discovery in any of them. The probable rapid exhaustion of the supply of coal fields with which England is threatened, however, may lead to the solution of the question of the possibility of the existence of the carboniferous strata in this district. If the strata in question exist, they must be found at a great depth; but there is every possibility that the continually increasing price of coal would justify the attempt at least to raise that material from a depth equal to that of the Monkwearmouth mine, or about 1 800 or 2 000 feet from the surface. The extreme depth that has been tried in the Weald, for an Artesian supply of water, or for coal, is about 800 feet, so that there is reason for continuing the operation, in the hope of the latter discovery, at any rate. The chances of the first discovery are very small indeed, yet we find that the excavations carried on, with the hope of meeting with a spring of water, are numerous, whilst those undertaken with a view to the discovery of coal are few and far between, and are always conducted upon a

decided want of geological principle. Even Sir John Herschel was mistaken in his judgment upon the borings that were undertaken at Bexhill, in Sussex, with the hope of finding coal, for that eminent authority, reasoning upon the necessary sequence of the earth's crust, stigmatised the folly of the search in this quarter; but it is now known that this is not so, and that in Belgium and in France at least, the carboniferous strata occupy a very different position in the series of deposits from what they might have been expected to have done. There is, then, an extreme probability that the search for coal along the anticlinal line of the Weald formation would be ultimately rewarded with success; but whoever undertakes to make it must prepare himself for the chance of disappointment and difficulty, and he must be prepared also to see the fruits of his labour and risk ravished from him. It may be important to add that at Marquise, in the Pas de Calais, and about sixteen miles from the port of Calais, the results of a late boring have been such as to prove the existence at that locality of the coal measures. Surely this ought to encourage the attempt to find the same formations in the prolongation of the line of upheaval of the Weald on the English side of the Channel, and thus connect the South Wales coal field with the North of Europe deposit of that description.

The application of the principles of geology that have been ascertained of late has a singular interest at present (in 1862), when there are many attempts being made to persuade the City Corporation to incur the expense of sinking an Artesian well, in order to supply the proposed Smithfield Meat Market. It must be evident —from what has been stated above of the results of the borings at Calais, Ostend, Highgate, and Harwich—that at any rate there would always be the risk, nay, almost the certainty, of positive failure in seeking for a supply of water from this source. The greatest chance of meeting with a

copious supply would be found in sinking a well on the east bank of the Fleet, and pumping the water obtained from the chalk there to the market. There is, moreover, a great probability that, in the case of the City authorities obtaining a quantity of water from this source, it would be found to be of a greater degree of purity than the water from the wells of the Kent Water-Works, the Gravesend, or the Bocking wells. The latter differ from the normal composition of chalk waters, inasmuch as they are highly charged with the nitrates, in the case of the Kent Water-Works, and the chloride of sodium in the other cases named. But the conditions of supply to the underground spring, on the east bank of the Fleet, seem to promise different results from those that are met with in the cases of the other wells; as the feeding ground is comparatively free from buildings, and there is not the same interchange of the salts of the sea water, which doubtlessly accounts for the presence of the chloride of sodium in the waters of Gravesend and Bocking. The question of the composition of the chalk waters is, indeed, one that merits peculiar investigation; there are rarely found two districts that yield waters of identical composition, and there do not at present appear to be any known laws affecting the difference in them. The nature of the water that is obtained from the lower part of the valley of the Fleet is, however, sufficiently known to prevent the entertaining dread of the quality of what it would yield.

CHAPTER VIII.

PUMPS AND APPLIANCES FOR RAISING WATER.

As it is desirable to make this work as practical as possible, the space which might be taken up in describing methods of raising water in ancient times, or those proposed in our own, but which, practically, have not superseded the pump, or common windlass and bucket, is passed over. All elementary books on hydrostatics and hydraulics contain descriptions of Archimedean screws, endless bands, Jacob's ladders, Persian wheels, &c.: to such works the reader must therefore be referred. The common bucket and windlass is the simplest arrangement for raising water from wells, and, in parts of the country where wells are deep, is used in preference to pumps, except where a large quantity of water is required; for, as will be presently shown, the common pump will not draw water more than 30 or 33 feet at most,—sometimes, taking imperfections into account, not more than 25,—while the deep-well pump, from its situation, rods, rising main, &c., is a more expensive affair than the bucket and windlass. In some districts the springs are within a few feet of the surface; here a pole with a hook at the end, to which the bucket is attached, supplies the place of the rope and windlass. Where a windlass is used, it can be worked either by hand or by horse or donkey power, the horse-wheel working either horizontally, as in the case of a pug or clay mill, or vertically, the animal working from inside the wheel or drum. Often the windlass, though worked by hand, is driven by second motion, a spur-wheel situated on it gearing into a pinion fixed on the axle, to which the winch is attached. Examples of the above methods of raising water are com-

mon in parts of Hertfordshire; they answer very well for small quantities of water periodically required, but for filling cisterns or reservoirs, &c., are of little use, and for such purposes pumps are always adopted.

The principle of the pump is very simple; in its most common form, the pump consists of a barrel truly cylindrical, into which fits the sliding portion of the pump, or bucket, as it is called. This bucket has a valve in it opening upwards; a similar valve, also opening upwards, is situated at the bottom of the barrel, which is called the sucker. The action of the pump is as follows: when the bucket is drawn up in the barrel, into which it fits air-tight, a partial vacuum will be formed under it, more or less complete according to the perfection of the apparatus; the valve in the bucket will be kept shut by the pressure of the air above it, while the valve in the sucker will be forced upwards by the water rising into the barrel, which water is forced into the vacuum under the bucket by the air pressing on the exposed surface in the well; in other words, by abstracting the pressure of the air from off part of the surface of the water, that portion under the bucket is forced upwards by the pressure on the remaining portion of its surface, just as, in compressing a bladder full of any liquid, the latter will gush out at any aperture, there being little or no resistance at that point. Supposing the up-stroke of the bucket complete, and the space under it charged with water, on commencing the down-stroke the water cannot return downwards through the sucker, for the valve in it will be shut by the weight of the water, but the valve in the bucket will be raised by the same effort; thus the position of the water will be changed from under to over the bucket. It is manifest that, on the up-stroke of the bucket, the water resting above it can be raised to any height required; but the height to which the water under the bucket can be thus raised above the natural level of the well is limited by a law of nature within the range of

from 30 to 33 feet, before stated. The explanation is as follows: the pressure of the air on the surface of the water balances a column of the latter in the suction-pipe; it follows, that if the height of the pipe be such that the column of water equals in weight that of a column of air of the same diameter, and of the total height of the atmosphere, the column of water would be pressed upwards no longer, for the two weights would be in equilibrium. That the comparison should be made with a column of air of the diameter of the pump, and not the total weight of the air pressing on the whole surface of the water in the well, will be understood by imagining for a moment the effect of having a pipe one square inch in area, and of length sufficient to contain a quantity of water greater in weight than that of a column of air also one square inch in area, and of the total height of the atmosphere: on filling this with water, its lower end being open and immersed in the well, the effect would be that the pressure on the square inch under the pipe would be greater than the pressure per square inch of the air on any other part of the surface of the water in the well. The particles of the water, from their extreme mobility, would transmit this in all directions; the extra pressure per square inch being divided equally throughout the mass, would react against the total atmospheric pressure, causing the latter to yield; the general level of the water will rise from the additional quantity running in, and this will continue until there is an equilibrium of pressure per square inch between the water in the pipe, pressing on the surface of the water in the well, and the pressure of the atmosphere. A comparison of the relative weights of water and air would appear to warrant our placing the sucker of a pump at a greater height above the surface of the water in the well than is usually adopted in practice; but the imperfections of the different parts of the machinery do not admit of its ever being carried beyond from 25 to 28 feet at the utmost.

Forcing pumps are used when the height to which the water has to be raised exceeds the above limits, and they may be of two kinds, viz., pumps in which the column of water which has already passed through the piston is lifted by it, or pumps which have valves at the feet of their rising mains, through which the water is forced at the down-stroke of the piston. At great depths the former description is never employed, because it would be necessary to lift the whole column of water at the up-stroke of the pump. When the latter is used, it is customary to combine the suction and the forcing principles as far as possible, in order to diminish the weight to be raised.

Generally speaking, the suction tube is placed immediately under the working part of the pump, in the same straight line, and the rising main is placed by the side. Sometimes, however, the pipes are made continuous, and the pump is upon the side; and in other combinations a single piston is made, both to raise the water by suction and to force it into the rising main at each up and down stroke of the piston.

When a greater quantity of water is required to be discharged with a continuous flow than the well or spring is able to furnish, it is important to place the end of the pump under the surface of the water, so as to ensure a good reservoir at starting. The following Table, giving the contents due to one foot in depth of water, in wells of different diameters, will be found to be useful in many calculations respecting their yield:

Diameter. ft.	in.	Contents in cubic feet.	Contents in gallons.	Diameter. ft.	in.	Contents in cubic feet.	Contents in gallons.
2	0	3·1	19¾	5	0	19·6	122
2	6	4·9	30½	6	0	28·3	176
3	0	7·1	44	7	0	38·5	239
3	6	9·6	60	8	0	50·3	313
4	0	12·6	78	9	0	63·6	396
4	6	15·9	100	10	0	78·5	489

In the plunger pump the bucket is dispensed with, and in

its place a solid cylindrical plunger slides air-tight through a stuffing-box. The up stroke of the plunger will cause a partial vacuum in the pump-barrel, and water will therefore rise into it through the lower clack. The barrel of the pump communicates with another and similar clack opening upwards; the down stroke of the plunger will therefore force the water from the barrel of the pump through this valve, which, of course, by shutting, prevents the water returning to the pump. In addition to many other reasons for employing this pump in certain situations, the little trouble in attending to the packing, compared with the removal of the buckets for the purpose of putting fresh leathers on the clacks of the other descriptions of pumps, causes it to be a great favourite with workmen.

More pumps are usually used in well-work than one, except in very small wells, where the motive power is manual, and acting on an ordinary pump-handle: where that or any other force acts through the medium of wheel-work, the irregularity of motion caused by the varying resistance of the pump is so great as to require the effort to be regulated either by placing a counterweight so as to render the up and down stroke of the pump uniform in resistance, or to fix more than one pump. The nearest approach to equality of resistance takes place when three pumps are used, worked by an axle having three cranks set at an angle of 120° with each other. When the power applied to them is uniform, and not governed by a fly-wheel, this arrangement is worthy of adoption. But a serious objection exists with respect to the use of three pumps on the score of expensiveness, and the increased friction arising from the three barrels, buckets, and rods; so that, whenever it is possible, it will be found advisable to employ two pumps and to equalize the effort exerted upon them by means of a fly-wheel. The above remarks, it must be remembered, only apply to pumps worked through the intervention of wheel-work.

In the case of large pumping engines, which act directly on the pumps themselves, all the details of the subject are altered. It sometimes is desirable, in very deep wells, to raise the water in separate lifts, that is, the pumps are situated at various heights up the shaft; the lowermost one supplies a cistern from which the pump directly above it draws, and this in like manner feeds the pump situated in the next lift. The advantage of this arrangement is obvious. Each pump has a comparatively small weight of water to raise; a lesser strain is thereby occasioned, and in case of any leakage of the clacks or buckets, its effect is not so disadvantageously felt. The materials of which pumps are made differ, they being either of wood, lead, iron, brass, or gun-metal. Wooden pumps are now nearly out of date; leaden pumps, with wooden buckets and suckers, are extensively used for shallow wells, raising water from ponds, reservoirs, &c.; iron pumps are also used for the same purpose, and also for fixing in deep wells; they are inferior to brass or gun-metal, as being more liable to corrosion, but they are cheaper, and experience has shown them not to corrode so rapidly as might be supposed; indeed, it is not so much in the barrels of the pumps that corrosion takes place (water alone having no oxidating power) as in the rods, nuts, screws, and other parts exposed to the joint action of air and water. Pump-rods are either of copper or iron; copper is the best, but the dearest, the iron ones corroding very fast, especially where they pass through the guides: the junctions of the rods are scarfed and secured by brass or iron ferrules. The rods can be thus readily taken asunder by merely loosening the ferrules, which is effected by driving them with a hammer upwards. The guides for keeping the rods strictly vertical are either made of wooden cleats, or of brass rollers bolted to cross timbers; the former plan is the simplest, and by many considered as the best, for, the guides being inexpensive, it is usual to place more of them than when

rollers are used, and is, therefore, usually adopted. Formerly the distance between these guides exceeded the present practice, but experience has shown that a distance of six feet is the most advantageous where the works are not on a large scale.

In computing the quantity of water a pump will throw at a given velocity, and the power required to work it, the following memoranda will be found useful.

Cubical Content and Weight of Water.

1 cubic foot of water contains 6¼ gallons, and weighs	1 footweight.	
1 gallon of water contains 0·16 cubic foot, and weighs	0·16	,,
1 pound of water is contained in 0·1 gallon, and is	0·016	,,
1 cwt. of water is contained in 11·2 gallons, and is	1·8	,,
1 ton of water is contained in 224 gallons, and is	35·84	,,

1 footweight or talent = 62½ lbs. = 1 000 ounces.

The quantity of water thrown by a pump in any given time will equal the cubical contents of the pump-barrel comprised in one stroke of the bucket, multiplied by the number of strokes: this is evident, as in one stroke a quantity is discharged equal in diameter to the barrel, and in length equal to the play of the bucket. Thus, suppose a pump 3 inches diameter, 9-inch stroke of bucket, working 27 strokes per minute,—required the quantity of water delivered? To find the contents of the pump we have to square the diameter $\times$ by ·7854 and then $\times$ by the length of stroke. Or, $3^2 \times 0·7854 \times 9 = 63$ cubic inches nearly. And the quantity of water raised per minute is $63 \times 27 = 1701$ cubic inches, or very nearly a cubic foot, that is, very nearly 6¼ gallons. Such calculations, applied to large pumps, would have all the terms in feet instead of inches. In ascertaining the power necessary for working the same, it must be borne in mind that the resistance opposed to motion is the friction of the bucket and other moving parts, the weight of the rods unless they are counterbalanced, and the weight of the water moved. The *weight of the latter,* whatever be the diameter of the pipes

to or from the pump, is equal to that of a cylindrical column the diameter of the pump-barrel, and in height equal to the distance from the surface of the water in the well to that of the reservoir into which it is delivered; in other words, the total height raised. The friction of the working parts depends on various circumstances, and that of the water on the material and size of the rising main, suction pipes, &c.: one-fifth the total weight of water is usually allowed for friction, and though it is manifestly absurd to so make it a fraction of the weight of the water when it really depends on other matters, yet the above rule is sufficiently accurate in practice to ensure adequate power.

The above calculation only applies to the resistance to motion; that, together with the speed at which the work is done, really is the test of the power required: multiplying, therefore, the total resistance by the speed per foot per minute that the pump-bucket raises the water, the result will be an amount by which to compare the relative power of the prime mover, whose useful effect multiplied into its speed per foot per minute must exceed that of the work done. Commercially it is allowed that a dead weight of 33,000 lbs., raised one foot per minute, shall equal a horse-power; a comparison is therefore at once established by which to measure the work, and also to provide the power. We will proceed to apply the above datum to the preceding example, supposing the total height the water is to be raised is 99 feet, and employing the following approximation, viz., that the number of pounds of water avoirdupois contained in each yard of pipe is equal to the square of the diameter of the pipe in inches.

In 99 feet are 33 yards, which, multiplied by 3 squared, or 9 = 297 lbs. The bucket makes 27 strokes per minute, moving the column of water each stroke 9″, in all 27 × 9″ = 243 inches, or 20 feet 3 inches per minute. Multiplying the resistance, 297 lbs. × 20 speed in feet per minute, we have = 5 940 lbs., moved over one foot per

minute. Add for friction, say 1 000, and 6 940 lbs. will be the momentum required in the prime mover, or rather more than one-fifth of a horse-power.

Should it be required to know whether a man, acting on a winch connected by wheel-work with the above pump, can work it, the comparison is easily made. Suppose the revolutions made by the winch 50 per minute, the distance travelled by it in one revolution four feet, and the man's force continually acting throughout the revolution to be a pressure equal to 40 lbs.; we have 40, the force, multiplied by 4, the distance of one revolution, equal to 160, multiplied by 50, the number of revolutions, equal to 8 000 lbs., moving over one foot per minute,—an amount quite sufficient to work the pump.

The size of the pumps and number of them being determined, the prime mover is the next question. In all cases where a continuous supply of water is required, or where large cisterns are to be filled, manual labour, even for small pumps, will be found the worst and dearest. Water power is seldom, for obvious reasons, applicable. Wind can sometimes be applied, and, where it can be depended on, will supersede all others; but it is only in peculiar situations that it can be trusted. The above motive powers, however, all give place to steam, which can be used under all circumstances. On a large scale, the use of steam is sufficiently extensive; but its advantages in superseding manual labour in filling cisterns, &c. have not hitherto been sufficiently appreciated. The work can be done much more rapidly, and it is nearly self-evident that, even with such a small-sized pump as the one alluded to in the foregoing examples, a man's time is better applied in tending a small engine for three or four hours than in slaving like a machine for double or treble the time. It is clear he must rest, while the engine never tires; and equally so, that he who tends the engine is, after pumping, an *intelligent servant*, fit for other work, while he who performs the

functions of a machine is, by the very nature of the work, unfitted for any higher occupation.

When pumps are applied to an existing horse-wheel—I say existing, for few now choose horse-power in preference to steam, unless the wheel is already erected—the number of revolutions of the wheel should, by a train of toothed wheels, be so proportioned as to work the pumps at the speed best suited to them. This velocity depends greatly on the size of the suction and delivery pipes; the larger the pipes, the quicker may be the motion. The size of the pumps, and the height of the lifts, must be taken into account. When pumps work too quickly, they are apt to jerk, and are sure to strike their clacks, with great force, into their seats; when too slowly, the motion of the pump becomes quivering. The following examples may be cited to illustrate the variations of speed admitted in practice.

Situation.	Size of Pump.		No. of effective strokes.
Hampstead Water-Works .	2′·3″ stroke	9″ diam.	15
Kilburn Brewery	9 ,,	3 ,,	18
Camden Station	2·0 ,,	8 inches	20
Kingsbury	8 ,,	3″ diam.	24

When steam is applied to pumping, if the machine be large enough, it should be applied directly to the pump, or through the intervention of a beam alone: this arrangement is adopted in the ordinary pumping engine, both with forcing and lifting pumps. The motion of the Cornish engine is single-acting, that is to say, the steam only acts on the piston during its down-stroke, the weight of the pump-rods, &c., acting on the opposite end of the beam, completing its up-stroke. The single-acting engine has one disadvantage when working a single-lifting pump, situated in a deep well; that is, a certain amount of power is consumed in raising the pump-rods; and this can be obviated in many ways. The one generally adopted is as follows: the work being divided, say into two lifts, for the lower a lifting-pump is used, and for the upper a forcing

or plunger-pump, similar in principle to the feed-pump of a steam boiler. The acting stroke of the plunger being the down-stroke, the power required in previously lifting the pump-rods is not lost, inasmuch as in their down-stroke the power is returned to the work. The up and down stroke of the piston may be thus represented, omitting friction: the down-stroke of the piston raises the pump-rods and weight of water on the lower lift, and on the upper lift as far as the plunger-pump sucker; the down-stroke of the pump-rods raises the piston, and forces the water from the plunger-pump to the top of the lift: thus, in effect, the only work done, if the lifts be so arranged, is in raising the water, and an amount of counterbalance sufficient for raising the steam piston. When plunger-pumps are used, wrought-iron rods are dispensed with, the rods being in a state of compression, and if of wrought iron, unless inconveniently large, would spring and buckle; wooden rods or poles are therefore adopted. Cast-iron rods have been tried, but not with the same success as wood, taking into consideration the relative strength, lightness, and durability of the two materials. When small pumps are worked by steam, the plan of engine above alluded to is seldom used, on account of the complication, first cost, and wear and tear: a steam-engine of the ordinary construction working the pumps at a less velocity than the steam piston is found to answer the purpose better, though an increased expenditure of fuel is attendant on the choice. Sometimes the speed is brought down by intervening wheel-work, as illustrated by the engine at the Hampstead Water-Works, Hampstead Heath, and also by the engine at the well at Kingsbury. At other times the speed of the pumps is reduced from that of the steam piston by giving the latter a longer stroke than the pump-buckets or plungers have. An example of this is to be found in the works at the Camden Station.

When a well is completed as regards its digging, stein-

ing, boring, fixing of pumps, engine, &c., the care of the works is a matter of more importance than owners usually think. Periodical visits should be paid to the pumps, for the purpose of ascertaining their condition, and keeping in order the clacks, buckets, stuffing-boxes, and various moving parts, greasing such as require lubrication, &c. A permanent windlass should always be fixed, or iron ladders, to give access to the well. An apparatus for blowing fresh air down the well, if it is at all deep, should be provided; and the simplest machine for this purpose is a kind of wooden air-pump, consisting of a vertical square box, open at the top, and at the bottom connected to pipes leading down the well. In this box, loosely fitting, slides a piston, or pump-bucket, made of a piece of flat wood, with one or more holes, covered on the under side by a leather flap, or valve, which opens a little way downwards. During the up-stroke of this bucket the air merely changes its position from the top to the under-side of the bucket; during the down-stroke the valve or flap closes; the air, therefore, will be forced down the pipe leading to the well. In addition to these, some method should be adopted for ascertaining the water-level, which varies, generally, by the pumping; a float on the water, attached to a wire, which, in its turn, is secured to a string passing round a pulley, will suffice for this purpose. A pressure gauge, such as that used for a steam boiler, is the most perfect arrangement for this purpose, though more expensive. The mode of application consists in leading a pipe from the gauge down to the bottom of the water in the well. If this pipe be filled with air, by means of a small pump, the air will necessarily be compressed more or less, according to the height of water above the aperture of the pipe. This compressed air, reacting on the mercury in the gauge, will correctly measure the depth of water. Were it not for leakage, and the absorption of the air by the water, the pump would not be necessary, the pipe alone would suffice.

APPENDIX.

THE QUALITIES OF WATER.

The object in sinking a well is twofold: first, that water may be procured in sufficient quantity within a convenient distance from the place of consumption; second, that the quality of the water shall be sufficiently good for the intended purpose. After all the labour expended in sinking a well, the yield of water may not only be extremely small, but defective in quality, owing to its impregnation with saline or other inorganic matter; or the well may be so placed as to be liable to contamination by organic matter, and then yield eventually an unwholesome supply; in either case the result may be so bad as to render it advisable or imperative to close the well. It hence becomes necessary to the well-sinker to have some knowledge of the various qualities and properties of water, and the requirements in this respect that must be kept in view while seeking a supply of water intended for a special object.

The uses to which water may be applied determine the degree of purity or special qualities necessary; these may be thus distinguished.

1st. Potable water, for drinking, cooking, or preparing food, and washing cooking vessels, making potable liquids, or, as medical men say, for internal use in any way admitting of its absorption or assimilation into the human system internally.

2nd. Washing water for baths, lavatories, cleansing *household* linen, or laundry work, and for use in any

way admitting of its absorption into the human system externally.

3rd. Flushing water, for flushing or washing floors, scrubbing buildings, flushing drains, sewers, closets, latrines, urinals, &c., watering roads and streets.

4th. Water for the supply of horses, cattle, birds, and other animals.

5th. Factory and engine water, for use in industrial arts and manufactures, in boilers of steam-engines, &c.

6th. Irrigation water, for purposes of agriculture.

Impressions with regard to Drinking Water.—Treating potable water first in order, from the higher degree of purity in it necessary, it may be noticed that perfectly pure water rarely exists in nature. It is believed that at some places, notably the water of some springs near Darjeeling, on the Eastern Himalayas, absolute purity of water does exist, from the reason that chemical science fails, at present, to detect any impurity in it, and that it is sufficiently pure for all photographic purposes without distillation. Even rain-water is not delivered in a perfectly pure state, as it carries with it the impurities and particles of dust, carbon, insects, organisms, fumes, &c., existing in the air; and further as, during collection in some vessel, tank, or roof, it acts as flushing water in cleansing the collecting vessel, it also collects all the impurities, dust, moss, fungoids, &c., that exist on the latter. Nominally, pure potable water may be manufactured by the process of distillation, and aërated to make it palatable, but even then it is liable to impurity from contact during these processes. Pure water, like the perfect human being, is an idealism to which we may tend but cannot reach.

The impurities in water are of two kinds: 1st, inorganic, gaseous, and mineral, now admitting of detection and quantitative assignment with exactitude under chemical analysis; 2nd, organic, living or dead vegetable and animal organisms, their excreta, spores, seeds, or germs: such

impurities of either class may be harmless, noxious, or positively poisonous to the human system. A distinction must also necessarily be drawn between original impurity, or impurity existing at the source of supply, and acquired impurity, accumulated during transit, delivery, distribution, or use.

Spring-water is naturally considered superior for drinking purposes to any water obtained from surface collection, from open river-channels, reservoirs, or lakes. It has undergone a process of natural filtration in the geologic strata through which it has permeated, and at the source is free from the liability to contamination from which river-water and lake-water suffer. As a rule, spring-water is bright, sparkling, and well-aërated, or, as ladies say, it looks pretty: such a test, however, is utterly valueless, as pretty water is sometimes deadly, and often unwholesome. The principle of "the nearer the source, the purer the water," may be mainly true, but is not absolutely correct. The flow of water along a course of open channel often enables its original inorganic impurities to be deposited, or partly neutralised, while if any organic impurity is introduced in such a course, this may be partly oxidised, assimilated by vegetation, or neutralised by the soil of the channel during flow in a certain distance from the place of contamination. Hence the above-mentioned principle may err greatly, not only with regard to purity, but also if asserted to hold with reference to wholesomeness.

For instance, let the Londoner, disgusted with Thames water, its complicated relays of filth, and the professional hypocrisy that declares it pure and innoxious, pay a visit to some of the charming hill districts of North Wales during their most attractive season: he sees grassy hill-sides, healthy herbage with grateful perfume, clear tarns, some peat-fields, or moss. The population and the agri-*culture amount* to nearly nothing: some sheep, an occasional

shepherd and dog, and traces of a few miners' burrowings, or prospective claims, perhaps long deserted. He thinks that with such surroundings the beautiful bounding water of the hill-side rill must be certainly wholesome, and perhaps nearly pure: he drinks, and is afterwards seized with severe lead-colic.

A similar trial of some very pretty bubbling springs in various parts of England may cause illness, clearly traceable to excess of inorganic matter in their waters, salts, magnesia, &c., or impregnation with gas. In such cases of serious ill effect due to invisible inorganic impurity in pretty water, the analyst could detect and quantitatively determine the noxious constituents.

Taking another type of spring-water for illustration. Very recently the Lambeth Water-Works Company were daily drawing two million gallons of spring-water, partly derived from about ten square miles of the gravel subsoil at Molesey. It was supposed that, as it had undergone a process of natural filtration in the gravel strata, it was wholesome. In this case the skill of the professional analysts and chemists was brought into use. After thorough investigation they pronounced it to be pure and wholesome water; the water was therefore used as drinking water for some time. Yet further examination and inquiry resulted in a belief that the water was very bad and dangerous, and at last some one pointed out that it was actually contaminated by sewage from several cesspools situated on the area whose subsoil was drawn on. Eventually the water was condemned by Dr. Tidy as unfit for drinking purposes. In this case thoroughly certified spring-water was actually dangerous.

Every Londoner is aware of the custom of water companies in employing analysts to give monthly certificates of the purity of the waters supplied by them. It may be a harmless custom apart from its deception in deluding the ignorant. These analysts can determine the amount of

mud, lime, and all the inorganic, mineral, and gaseous constituents of these waters to a nicety, and can truthfully assert a chemical purity, or a degree of chemical purity: the public imagine that this also means perfect wholesomeness, and is thus conveniently blinded.

The perfect wholesomeness of water is, however, dependent also on its freedom from organic impurities, organisms, spores, &c. These being mostly of very minute form, and largely composed of water and other matters, are destroyed or partly lost in the processes of the water-analyst: their presence can, therefore, rarely be detected by him. Minute quantities of highly diluted and partly decomposed animal excreta, which constitute organic impurity in the most dangerous form, baffle him entirely.

Under these circumstances the most natural step in progressive knowledge of the qualities of water is to refer to the morbid anatomist and microscopic biologist. Scientific men, as represented in the special type to which Drs. Lankester, Redfern, Hassall, Tyndall, Sanderson, and Pasteur belong, are intimate with the habits and conditions of existence and destruction of a large number of minute organisms, animal and vegetable, in a perfect and in embryotic state. Such men are unfortunately very few, their investigations are laborious and lengthy, besides being sometimes uncertain in result. Much, therefore, as it might be wished to entrust all periodical examinations of supplies of drinking water to eminent microscopic biologists, this can hardly be hoped for as long as the public remain satisfied with the speedy and delusive results offered by the analyst. Besides, the science of the microscopic biologist is yet hardly sufficiently advanced for such purposes: it is very doubtful whether he can detect at all many of the most noxious germs that exist in impure water, or even render a good account of them.

Hence, after accepting all the partial information afforded by the ordinary water-expert, the water-analyst,

and the microscopic biologist, the sum total is inadequate, useful though it undoubtedly is.

To the question then arising, "What next can be done?" it may be replied that only two courses remain. One, direct experiment on the human being in the form of observation of the effects of impure water in producing disease, sickness, and death; the other, careful selection of pure sources of water supply, and avoidance of subsequent contamination. The former is the province of the medical man, the latter that of the civil and hydraulic engineer.

The whole is therefore a complicated matter, calling forth the energies of four professions.

Natural Appearances and Indications.—Taking first in order the natural appearance of water and the evidences to our unaided senses that enable or help us to judge of its fitness for drinking.

The turbidity of water or its freedom from turbidity is perhaps the first quality to be noticed; muddy, or as it is often termed, dirty, water may be objectionable. It is true that one does not wish to drink mud, and that some slimes are exceedingly foul, being the breeding ground of a host of aqueous organisms; hence it is necessary to allow muddy water to settle and deposit its sediment, and to draw off the clear water before using or treating it in any way. It would, however, be a great mistake to reject all muddy water as utterly unfit and finally as useless for drinking.

The process under which suspended matters are precipitated is a very simple but an exceedingly useful one. The finely divided earth, whether clay, loam, or sand, carries with it, in falling, a very large amount of organic impurity (provided it exists), and thus cleanses the water. Hence, in dealing with strange drinking water, it is a safe process to mix some *clean* earth with it, to stir it up, and render it as muddy as possible, and then allow it to settle and clarify itself before using it for drinking. In this process

one provides a home for, or conveniently localises, a large proportion of the organisms and animalcules that may possibly have been roaming in the water. All slime resulting from any corresponding process, as that from the depositing beds of large waterworks, should invariably be burnt or incinerated: it is a most dangerous substance, even its exhalations may be deadly.

The turbidity of water is, as thus shown, not a serious objection, unless either the mud itself be foul or semi-putrescent, as in stagnant water, ponds, pools, marshes, and lagoons, left to stagnate for a few months in the year, disused wells, or unless the mud has been contaminated by excreta, or is partly composed of decomposing vegetable matter.

Proceeding to the transparency or translucence of water—this is certainly advantageous, for the negative reason that opacity shown by a milky tinge is or may be indicative of most serious defect, drainage from corpses, old cemeteries, churchyards, or ancient burying grounds. Such water, sacred though it may be from the consecration of its locality, or from being named as a holy spring or of holy reputation, is yet most deadly. The opacity of water may in many cases be due to some other cause, but unless some scientific man has clearly traced it to some harmless origin, the water should be scrupulously avoided. The absence of opacity, shown by an extremely pure blueness of colour when in large quantity, is one of the most valuable of the simple evidences of pure water, that is to say, it affords good evidence as far as it goes.

The brilliancy or sparkling quality of water may be due either to fixed air, gas, volatile or mineral constituents, and being certainly an evidence of the absence of stagnation is therefore advantageous. As it is seldom that sparkling water tastes flat, this is therefore pre-eminently the ladies' test of drinking water, but it is valueless as a test of its wholesomeness.

Freedom from smell is certainly an advantageous quality; a putrescent smell may indicate either actual decomposition or the presence of sulphuretted hydrogen or other objectionable gases in the water. Most water having no appreciable smell when fresh drawn, it is a good plan to keep a sample of it in a moderately warm place in a clean bottle filled three-quarters full and well corked with a clean cork. If after a few days there is no perceptible odour on uncorking the bottle, and the original colour of the water be not impaired, it may be said to have stood well the smell-test.

Last, the taste of water. An insipid taste affords no evidence of impurity or unwholesomeness. Pure distilled water and clean rain-water taste flat; this being due to the absence of air, gas, and volatile constituents, usually present in spring and river water. A bitter taste in water is generally ascribed to the presence of vegetable organic carbon, or is considered due to organic impurity from a vegetable source—such as decayed leaves, rotten wood, dead marsh-plants, &c. A pure soft taste (not exactly sweet, though often so termed) is almost an indispensable accompaniment to wholesome water. A positively and unmistakably unpleasant taste in any water, after the removal of sedimentary deposit (as before mentioned on page 129), is quite sufficient cause for condemning it entirely as potable water, however well it may have stood all other ordinary tests.

The forementioned qualities—turbidity, transparency, colour, brilliancy, odour, and taste—may be supposed to be within the powers of discrimination or discernment of most persons, or certainly of a great number of persons. It is generally believed that most persons—with the few exceptions of extreme cases of colour-blindness, defective palates, &c.—are in full possession of the faculties of sight, smell, and taste. This is a popular delusion; most persons are merely endowed with such faculties to an extent suffi-

cient for carrying on the coarser requirements of animal existence, ordinary labour, and trade: a higher, or even a full development of such faculties, arriving at a moderate or a refined power of discrimination, is comparatively rare, and is generally due to continued and extended use of such faculties, either in the individual, the family, the class, or the race to which he belongs, or in several ways. The amount of discriminative power required for judging slight differences of colour, taste, smell, transparency, &c., in potable waters, is beyond that possessed by most people; hence it is best to relegate such matters to those that have such power, and in many cases to those accustomed to deal with them.

Testing for Traces of Impurities.—The following are the chemical re-agents commonly used in testing water for traces of inorganic impurity of various sorts, any turbidity produced by them affording proof of the existence of the corresponding substance in the attached list:—

Re-agent.		*Inorganic Impurity.*
Oxalate of ammonia	for	Salts of calcium, lime.
Lime water	for	Carbonic acid.
Nitrate of silver	for	Chlorine or chlorides.
Chloride of barium	for	Sulphur or sulphates.
Hydrosulphuret of ammonium, sulphuretted hydrogen	for	Metallic substances, iron, copper, zinc, lead, and organic matter.
Dilute sulphuric acid	for	Barium.
A solution of peroxide of hydrogen	for	Manganese.

Arsenic is detected by Marsh's process.

The bleaching of a solution of permanganate of potassium affords evidence of the presence of nitrites or of nitrogen.

The total amount of solid ingredients contained in water may generally be roughly arrived at by evaporating to dryness in a platinum vessel a known quantity of it, and weighing the dry residue; but this method is inexact when earthy chlorides and sulphates are present.

The hardness of water may be judged of by the soap

test; by pouring in an alcoholic solution of soap, and noticing the amount of it curded, or by the amount of lather yielded in it by soap in comparison with that afforded by the same amount of soap in water of approximately known hardness. This quality of hardness or softness is not only important from an economic point of view, in saving soap in washing-water; softness is important in drinking and in cooking water—its effect in making tea is very marked—and in factory work, and in boilers of steam-engines, it is no less great, from diminishing the amount of fur or incrustation from repeated boiling.

Despatch of Water to the Analyst.—The foregoing are the modes of testing qualities of water within the powers of nonprofessional persons: when anything further is required it is usual to forward samples of water to an analyst. Such samples should be carefully taken and placed in thoroughly clean bottles (washed with sulphuric acid, and afterwards much rinsed), having clean stoppers or new corks, and properly sealed: half a dozen bottles nearly full are enough for a single sample. They should be accompanied by a short account of the time, place, and circumstances under which they were taken, and details of any conditions or surroundings that might affect their composition or ingredients, noticing more especially whether any suspected contamination is of vegetable, animal, or mineral origin.

In asking an analyst for an exhaustive quantitative analysis of samples of water forwarded to him, it must be borne in mind that, besides receiving the tribute of a high compliment, he is required to spend his hard-gained skill in operations that may extend over several weeks; and that his results, though actually comprising an estimation of organic residue, or residue of organic matter, do not estimate the whole organic impurity, but are really confined to but little beyond a good estimation of inorganic substances. It is, therefore, more usual to limit the de-

mands on the analyst to the quantitative determination of certain well-known special substances, and to state the special purpose, whether for drinking, washing, or manufacture, for which the water is required, thus dispensing with needless research and labour. As the processes of various analysts differ, it is often advisable, also, to ask that some mention of the processes adopted may accompany the results of the analysis. Without some such safeguard or provision, the inquirer may place himself in a predicament analogous to that of the half-poisoned man who had swallowed a bottle of some powerful unknown stuff that a doctor had recommended as "sure to do him good." A knowledge of the processes adopted in the one case is as useful as the prescription might have been in the other.

Analysis of Water generally.—The operations of the water-analyst are generally directed to determine the following results:—

1. The amount of dissolved matter, or matter in solution.
   (*a*) The total solid impurity.
   (*b*) The volatile and gaseous constituents.
   (*c*) The segregated impurities of either sort that are supposed to be residues of organic impurity.

The substances usually searched for in water-analysis are lime, magnesia, soda, potassa, alumina, silica and oxide of iron; metallic salts, especially of lead, soluble salts, insoluble, or earthy salts, carbon, carbonic acid, chlorine, nitrogen, ammonia, sulphuric acid, phosphoric acid, nitric acid, iodine, and bromine.

The separative determination of the following is also usual:—Albumenoid ammonia, nitrogen as nitrites and nitrates, carbonic residues from organic matter.

   (*d*) The specific gravity.
   (*e*) The estimation of hardness, both temporary and permanent, according to conventional scale.

2nd. The amount of suspended matter or sediment.

The separate quantitative determination of the above substances under the two heads of

(*a*) Mineral matter.

(*b*) Residues from organic matter.

As the proportion of such matter in waters is necessarily small, the various units that may be used by the analyst are worthy of consideration.

The present ordinary English medicinal units, with their complicated interdependence of weight of capacity and intricate mode of subdivision, may be entirely set aside as unsuited to analytical purposes. The principal defect in that system is that the weight units do not correspond with the capacity units, and neither of them are truly formed on cubic units. For convenience there should be complete correspondence among the three sorts of units.

The units most suited to English analytical purposes are on the following scale:—

$$1 \text{ cubic foot} = 1\,000 \left\{\begin{matrix}\text{cubic tithes,}\\ \text{or}\\ \text{fluid ounces}\end{matrix}\right\}; \ 1 \text{ fluid ounce} = 1\,000 \text{ fluid mils.}$$

$$\left.\begin{matrix}1 \text{ foot-weight}\\ \text{or}\\ \text{talent}\end{matrix}\right\} = 1\,000 \text{ ounces}; \ 1 \text{ ounce} = 1\,000 \text{ mils.}$$

Thus if we obtain by analysis any proportional constituents, either by bulk or weight, in a cubic foot of water, or in a foot-weight of it (through which its specific gravity is determined direct) the millionth parts of either of these units are respectively the fluid mil and the mil, which are subsidiary units most convenient for expressing the small quantities or proportions commonly occurring in analytical results. The constituents per million parts are thus simply expressed in mils.

As river-water with an appreciable amount of sediment is most convenient for exemplifying the use of these units, the following analysis, extracted from [p. 130] "Jackson's Hydraulic Statistics" (London, Allen, 1875), is here given. It applies to the water of the same river, sampled at various

dates in the same year, 1874, which, from its fertilising qualities, naturally contains matters in large quantity that can be found only in smaller or almost inappreciable quantity in potable spring-water or deep well-water. The analysis is hence more convenient for purposes of general illustration; it will also be referred to later on as illustrating the qualities of irrigation-water.

ANALYSIS OF RIVER WATER IN 1874, GIVING THE CONSTITUENTS PER MILLION PARTS.

DISSOLVED MATTERS.	8th June.	10th July.	12th August.	20th Sept.	12th October.
Lime	41·67	39·92	44·22	42·60	23·09
Magnesia	16·23	51·13	10·30	6·17	4·83
Soda	12·01	7·44	5·87	3·01	5·04
Potassa	24·75	10·62	15·01	41·20	23·48
Chlorine	16·43	8·51	6·28	2·09	4·91
Sulphuric Acid	28·08	28·38	18·37	19·96	19·08
Phosphoric Acid	Trace	..	..	..	Trace
Nitric Acid	Trace	..	..	..	Trace
Silica, Alumina, and Oxide of Iron	7·01	7·13	11·29	12·57	18·43
Carbonic Acid and loss	41·82	36·16	42·81	47·54	35·57
Residues from Organic matter	15·00	10·57	11·86	19·29	24·14
Total Solids	203·	163·86	166·01	194·43	158·57
Saline Ammonia	0·057	0·129	0·043	0·100	0·171
Albumenoid Ammonia	0·114	0·100	0·071	0·171	0·143

SUSPENDED MATTERS.	8th June.	10th July.	12th August.	20th Sept.	12th October.
Mineral	60·86	87·29	1307·43	483·43	332·14
Organic Residue	8·29	91·14	184·14	59·14	45·86
Total	69·15	178·43	1491·57	542·57	378·00

The average percentage of the sedimentary deposit from all the above samples was :—

Organic Residues	14·61	Soda	0·91
Phosphoric Acid	1·78	Alumina	6·18
Sulphuric Acid	Trace	Peroxide of Iron	15·15
Chlorine	Trace	Silica	55·09
Lime	2·06	Carbonic Acid and loss	1·28
Magnesia	1·12		
Potassa	1·82		100·

Analysis of Potable Water.—When chemical analysis is specially applied to potable water, the determination of its wholesomeness is the main object of the investigation, and quantitative analysis is applied to certain constituents separately, while others may be ignored in this respect. For instance, the separate determination of the weight of each constituent of the saline matters, either in solution or in suspension, is not generally required. A few of the former have some influence on wholesomeness, and afford proof of former contamination, and are hence important. Most of the latter, the mineral matters in suspension, are innocuous, and (excepting in cases where poisonous matters are suspected, such as lead, arsenic, barium, &c.) these are seldom separately determined. Frequently also, as the suspended matters, both mineral and organic, are inconsiderable in quantity, the water is shaken up before analysis, and the traces of these are included among the dissolved matters. The gaseous constituents of potable water are seldom extracted and volumetrically determined, for the reason that they vary but little in volume in very different waters, and are now believed to throw but little light on the character of water.

Hence, besides noticing the temperature and specific gravity of the water, determining its temporary and permanent hardness, and the total solid residue after evaporation, the constituents quantitatively determined are merely the following:—1. Organic carbon; 2, organic nitrogen; 3, ammonia; 4, the nitrites and nitrates; 5, the total combined nitrogen; 6, chlorine.

The expression, "Previous sewage or animal contamination," represents ten times the sum of (3) the ammonia and (4) the nitrates, less 0·32 a constant; thus, *e.g.*:—

$$10\,(1{\cdot}70 + 101{\cdot}02 - 0{\cdot}32) = 102{\cdot}40.$$

This conventional expression is supposed to indicate by standard the amount of original contamination per million parts, of which the nitrites, nitrates, and ammonia are the residue; the standard of comparison being the assumption that 100 parts of combined nitrogen was the average proportion existing in a million parts of ordinary London sewage, and that the constant 0·32 represented the proportion existing in rain-water. It is hardly reasonable to class potable waters as safe, suspicious, or dangerous, in accordance with quantities based solely on such a calculation; but this method is adopted by Drs. Frankland and Morton in the "Sixth Report of the Rivers Pollution Commission on the Domestic Water Supply of Great Britain," dated 1868, published in 1874. The safety or wholesomeness of potable waters cannot be in perfect conformity with such figures, as will be hereafter proved; hence this expression is here explained merely for the convenience of those that like to make use of it and deduce such quantities. But as the above-mentioned report affords the most modern statistics of analyses of waters for Great Britain, it becomes necessary to mention briefly the processes adopted in arriving at them.

Processes adopted by Dr. Frankland.—The total solid constituents were arrived at by evaporating to dryness as rapidly as possible half a litre of water in a weighed platinum capsule on a steam or water bath; after drying the residue at 100° C., the capsule is again weighed. The process adopted in determining the degree of hardness is not mentioned in the report; it was most probably the ordinary method by Clark's alcoholic solution of soap, or the hardness may have been deduced from the amount of

lime, magnesia, oxide of iron, and alumina shown by analysis, and represented by an equivalent of chalk according to Clark's rule.

1 and 2. Continuing to the estimation of organic carbon and nitrogen; the process adopted was that known as Drs. Frankland and Armstrong's evaporative method, a mode described fully in the Appendix to the Report at page 504. It will be needless to repeat it here; suffice it to mention that the mode of evaporation occupies much time, and is a complicated operation; that the mineral acids employed cannot but reduce the amount of organic matter before computation; and that the principle assumed in connection with it, "that a high proportion of nitrogen in the combined estimation of both nitrogen and carbon constitutes the higher organic impurity," cannot be invariably consistent. This method may be quantitatively superior to the old incineration process long ago condemned, but can hardly present any advantages over either the process of oxidation by permanganate of potash, or the albumenoid ammonia process of Wanklyn.

3. The estimation of ammonia was effected by Hadow's modification of Nessler's process, a well-known method, for details of which see p. 125, vol. XVIII. "Jour. Chem. Soc.;" also Wanklyn and Chapman's treatise.

4. The estimation of nitrogen in the form of nitrites and nitrates was effected by a modification of Walter Crane's process for the refraction of nitre. It consists in violently agitating with mercury a concentrated solution of the nitrite or nitrate with a large excess of concentrated sulphuric acid, when the whole of the nitrogen is evolved as nitric oxide. For the success of this method no chlorides should be present. Details of this now well-known process are given at p. 507 of the Report, also at p. 77, vol. XXI. of "Jour. Chem. Soc."

The total combined nitrogen represents the sum of the organic nitrogen, the nitrogen as a constituent of ammonia,

and the nitrogen occurring as a compound of nitrites and nitrates; that is to say, it is mere summation of a dangerous nitrogen, and a more and a less oxidated nitrogen that are inorganic and reduced to harmlessness; it is hence a comparatively valueless expression. Separation of the nitrites and nitrates would have been, on the contrary, a convenient arrangement, as the nitrites afford evidence of more recent contamination, and the nitrates of more remote and harmless pollution.

The method adopted for the estimation of chlorine is not mentioned, and hence was most probably the ordinary one, total precipitation with a standard solution of nitrate of silver.

The analyses of deep-well waters, following on page 144, are, therefore, results of the above process; they are comparable figures deduced on a uniform method, and are hence useful as far as they go. They certainly afford a vague idea of the extent of probable pollution at some vague antecedent date, and may be occasionally useful in helping to arrive at some opinion as to wholesomeness of water; but *as purely independent detached results*, no confidence whatever can be accorded to them.

Organic Pollution.—Let us consider what the various forms of organic pollution in water really are.

1. Vegetable excreta.
2. { Ordinary sewage and animal excreta.
   { Diseased sewage and animal excreta.
3. { Noxious living microscopic organisms.
   { Noxious dead microscopic organisms.
   { Embryo, seeds, spores, &c., of such organisms.

The range, the infinite variety of these matters, both in nature and in chemical composition; the infinite varieties of condition, both of simple decomposition, of dilution, and of inter-compounded chemical action, in which they may be found, render any approximate estimate of the original pollution quite untrustworthy. Also if we assume several

forms and modes of pollution to have existed, whether simultaneously or otherwise, these may even have partially counteracted each other direct, or the results of each other. To take only one phase of the matter. The innoxious and the slightly noxious living organisms in water are innumerable; they prey on each other and form food for each other; some of them also consume excrementitious matter; hence all trace of one source of pollution to water may entirely vanish and another one may have taken its place before the water can arrive at the analyst. Again, as to the residual matter from organisms accounted for by the analyst. Do the innoxious living organisms or the noxious living organisms yield more accountable residue? If we do not know this, the sum of the two may constitute evidence of wholesomeness rather than, as usually assumed, the contrary. Certain organisms, accompanying virulent disease, have extremely strong vitality. They are nearly indestructible under ordinary conditions, and in their line resemble man-eating tigers; but the weight of the residue of their membranes may have inappreciable effect on the quantity of organic nitrogen and carbon in the analyst's samples, while these same organisms may have cleared their immediate neighbourhood of other organisms and thus reduced the organic nitrogen and carbon.

We know that a pike may devour fish and small fry to a large extent, and yet add little to his own weight; the same principle may hold to an infinitely greater degree among animalcules.

There is plenty of evidence that water, highly polluted according to the analyst, often has no ill effect on public health, even over a long period; in these cases the specially noxious organisms are probably absent.

Mr. Baldwin Latham, C.E., whose eminence is principally due to the application of much skill and years of labour to matters connected with water-works and drainage, has pointed out that both the zymotic and the fever death-

rates for London, from 1868 to 1880, diminish with the increase of organic impurity in the water supplied, shown by Dr. Frankland's analyses. Mr. Latham also quotes Dr. Frankland's own words. "Chemical analysis is unable to detect those small quantities of morbific matter which are calculated to transmit disease to people drinking the water."

Even if we turn from Dr. Frankland's own method to the albumenoid ammonia process of Wanklyn that it supplanted, a mode of reducing all nitrogenous organic impurities into ammonia, and estimating the amount of the single result as indicating the organic impurity; on this subject, Dr. F. W. Anderson, in a letter to the "Sanitary Record," February 3, 1877, says, "I have never been able to obtain conclusive evidence that the dangerous elements of bad water are evolved as albumenoid ammonia; my observations tend rather to the belief that typhoid germs are easily oxidised and do not yield up their nitrogen as ammonia."

From the above it may be concluded that the analysts have till now entirely failed to distinguish between highly noxious and comparatively innocuous organic impurities in water. Hence the results of analysis render no absolute guide, although they may be useful in some respects for purposes of comparison, and for affording some clue or indication, when they are carried out on a uniform system over a multitude of cases.

In the following tabular extracts from the Report above referred to, the total combined nitrogen and the animal contamination columns have been omitted for reasons already given. The total hardness of the water is alone given, for the reason that the distinction between the temporary and permanent hardness is comparatively unimportant in potable water, as repeated and continuous boiling, by which temporary hardness is eliminated, is not *a common* domestic process. The results are expressed in

parts per million, instead of in parts per 100 000, for the reasons before mentioned, and for general convenience.

AVERAGE COMPOSITION OF SOME UNPOLLUTED SPRING WATERS DERIVED FROM VARIOUS STRATA, EXPRESSED IN PARTS PER MILLION.

AVERAGES FROM STRATA.	Total Solids.	Degree of Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
Granite and Gneiss	59·4	3·0	0·42	0·08	0·01	1·06	16·9
Silurian Rocks	123·3	6·8	0·51	0·14	0·01	1·78	18·4
Devonian Rocks and Old Red Sandstone	250·6	12·0	0·54	0·12	0·01	7·64	38·5
Mountain Limestone	320·6	19·8	0·87	0·10	0·01	2·24	46·3
Millstone Grits and Coal Measures	219·1	13·1	0·50	0·14	0·01	3·93	18·5
New Red Sandstone	286·9	18·8	0·65	0·17	0·01	3·30	21·9
Lias	364·1	30·1	0·73	0·19	0·01	4·67	24·8
Oolitic Rock	303·3	24·4	0·43	0·11	0·01	4·02	15·5
Hastings Sand and Green-sand	300·5	20·2	0·53	0·12	0·	3·26	29·8
Chalk	298·4	23·6	0·44	0·10	0·01	3·82	24·5
Drift Gravel and Fluvio-marine	613·2	37·6	0·86	0·19	0·01	3·54	27·6
Simple Rain Water	29·5	0·3	0·70	0·15	0·29	0·03	2·2

COMPOSITION OF SOME POLLUTED SPRING WATERS DERIVED FROM VARIOUS STRATA, EXPRESSED IN PARTS PER MILLION.

LOCALITY AND STRATUM.	Total Solids.	Degree of Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
Old Red Sandstone, Lanark	99·6	3·9	1·48	0·26	0·02	2·20	18·0
Yoredale Grits, Hawes .	284·6	26·6	1·74	0·33	0·05	1·31	12·0
Millstone Grits, Harrogate	79·0	4·2	1·96	0·45	0·03	0	13·0
New Red Sandstone, Bristol	1272·8	66·9	1·86	0·30	0·01	47·12	71·0
Lias, at Oakham (Rutland)	1018·2	88·6	2·92	1·13	0·01	3·22	18·0
Lias, Southam (Warwick)	573·0	33·5	2·82	0·54	0·11	3·97	20·0
Oolite, Beacon Spring, Bath	204·0	16·3	1·49	0·12	0·	2·70	14·5
Oolite, Beechen Cliff, Bath	418·0	31·3	2·74	0·18	0·	11·31	23·5
Hastings Sand, St. Leonards	419·2	16·9	2·24	0·54	0·88	4·78	96·0
Lower Green-sand, Sandgate	369·0	16·6	1·46	0·30	0·01	9·55	59·5
Chalk, Amwell . . .	284·4	16·3	6·99	0·97	0·	3·02	16·0
Chalk, Morden Park, Caterham . .	272·6	21·5	1·38	0·29	0·	6·67	14·0
Chalk, Chadwell . .	298·0	20·0	4·20	0·84	0·01	2·99	18·0
Chalk, Maidstone . .	391·6	27·9	1·38	0·44	0·04	8·70	35·0
Gravel on London Clay, Colchester . .	1547·0	53·0	1·76	0·57	0·01	73·95	275·0

AVERAGE COMPOSITION OF UNPOLLUTED DEEP-WELL WATERS DERIVED FROM VARIOUS STRATA, EXPRESSED IN PARTS PER MILLION.

AVERAGES FROM STRATA.	Total Solids.	Degree of Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
Devonian Rocks and Millstone Grit .	326·8	17·4	0·68	0·12	0·05	2·94	27·0
The Coal Measures .	831·0	35·7	1·19	0·34	0·44	2·07	180·5
New Red Sandstone .	306·3	17·9	0·36	0·14	0·03	7·17	29·4
Lias	709·8	30·1	1·46	0·27	0·01	3·89	44·2
Oolites	336·0	20·6	0·37	0·10	0·22	6·25	26·9
Hastings Sand, Green-sand, & Weald Clay	452·0	27·3	0·68	0·14	0·16	1·96	53·8
Chalk	368·8	27·7	0·50	0·17	0·01	6·10	27·6
Chalk below London *Clay* . . .	780·9	18·4	0·93	0·28	0·48	0·68	150·2
Thanet Sand and Drift .	538·4	22·0	1·13	0·20	0·72	1·16	63·2

COMPOSITION OF SOME POLLUTED WATERS FROM DEEP WELLS IN VARIOUS STRATA, EXPRESSED IN PARTS PER MILLION.

Locality and Stratum.	Total Solids.	Degree of Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
Devonian, Bromyard	851·2	41·2	1·77	0·48	0·	22·79	112·5
Carboniferous, Holyrood . .	925·4	27·9	3·28	1·75	0·56	9·50	79·5
New Red Sandstone, Lichfield .	320·6	18·3	1·63	0·38	0·03	4·89	22·0
New Red Sandstone, Liverpool .	867·0	35·5	1·35	0·38	0·05	86·78	126·1
Lias, Trowbridge .	1443·4	57·1	2·36	0·57	0·02	5·50	367·0
Oolites, Theescombe .	274·8	21·2	1·06	0·20	0·02	7·78	25·0
Oolites, Witney .	710·4	39·3	1·42	0·53	0·01	3·08	78·0
Lower Green-sand, Sevenoaks .	387·6	20·6	4·47	0·72	0·	2·52	59·0
Chalk, Arlesey . .	360·0	25·0	1·70	0·84	0·	11·30	18·3
Chalk, Carisbrook Castle . .	432·8	23·9	1·69	0·43	0 02	13·65	64·0
Chalk, Charlton .	928·0	42·6	1·39	0 28	0·	9·01	197·0
Chalk, Deal . .	2021·4	47·2	1·39	1·37	0·65	19·76	718·2
Chalk, Gravesend .	480·0	42·4	1·27	0·29	0·76	29·37	54·0
Chalk, Harwich .	2164·0	50·7	1·44	0·81	1·50	0·	1060·0
Chalk, under London Clay, Colchester	962·0	25·7	1·74	0·30	0·21	25·82	210·0
Chalk, under London Clay, Hounslow	824·0	34·3	2·73	0·42	0·01	8·46	90·5
Bagshot Sand, Sunningdale .	226·8	10·9	1·89	0·37	0·25	0·	30·0

Most of these wells were closed as dangerous.

COMPOSITION OF UPLAND SURFACE-WATER FROM UNCULTIVATED SOIL AND NON-CALCAREOUS STRATA, IN PARTS PER MILLION.

Stratum and Locality.	Total Solids.	Degree of Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
From Igneous Rock.							
Stream above St. Neots	59·6	0·9	5·53	0·30	0·02	0·	17·0
Teign above Exmouth	60·8	2·6	5·82	0·58	0·04	0·	14·0
Aberdeen, Supply from the Dee	43·6	2·1	3·99	0·29	0·	0·	5·6
Stirling Supply, Forth	64·4	2·7	4·81	0·45	0·01	0·	7·0
Dumbarton Supply, Clyde . .	72·6	3·8	3·86	0·71	0·02	0·	8·5
From Metamorphic, Cambrian, Silurian, and Devonian Rock.							
The Camel, nr. Mulberg Tin Mine	112·4	4·0	3·36	0·60	0·08	0·32	33·5
Ilfracombe Supply, Slade . .	124·8	6·9	2·47	0·32	0·	0·28	20·5
Bala Lake . .	27·9	0·4	2·27	0·01	0·	0·02	7·3
Windermere Lake, Lowwood .	57·8	4·0	2·99	0·76	0·02	0·18	9·9
Measand Beck (Cumberland) .	21·4	2·0	1·17	0·03	0·	0·	..
Keswick, fm. Skiddaw	43·4	3·4	1·32	0·24	0·01	0·	10·9
Loch Ness, at exit .	33·0	2·6	3·61	0·55	0·02	0·	8·5
Loch Katrine . .	24·0	0·9	1·85	0·22	0·01	0·	8·5
Ettrick, above Selkirk	62·0	3·7	1·83	0·15	0·	0·23	8·0
Glasgow, frm. Gorbals	88·0	4·4	3·39	0·49	0·02	0·18	11·1
Paisley, fm. Rowbank	116·8	5·9	5·21	0·68	0·02	0·	12·0
From the Millstone Grits and Noncalcareous Coal Measures.							
Lancaster Supply, Bleasdale .	45·8	0·9	1·29	0·22	0·01	0·	9·9
Bolton Supply, Entwistle . .	93·7	5·1	2·97	0·18	0·24	0·10	11·9
Liverpool, from Rivington Pike .	84·8	3·7	2·43	0·31	0·04	0·	15·3
Rochdale Supply .	88·2	5·1	1·34	0·	0·14	0·	10·9

OMPOSITION OF UPLAND SURFACE-WATER, &c.—*continued.*

ATUM AND OCALITY.	Total Solids.	Degree of Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
n Supply .	118·0	5·9	2·49	0·21	0·	0·10	11·4
well, near . .	78·0	3·7	1·87	0·25	0·04	0·21	11·5
Supply . .	81·4	3·2	1·33	0·31	0·05	0·29	11·0
ipply . .	150·0	8·3	2·58	0·25	0·	0·	13·0
orough, the . .	117·2	8·7	2·06	0·39	0·	0·27	10·7
Supply, Don	83·6	4·4	3·56	0·57	0·01	0·32	8·5
from Light- . .	55·4	2·2	5·09	0·41	0·03	0·14	7·0
Supply .	48·4	2·3	2·05	0·25	0·	0·10	11·0
gh, Crawley . .	112·8	6·1	1·87	0·31	0·01	0·	10·4
Tertiaries and ot Beds.							
outh Supply .	59·2	1·8	2·82	0·39	0·	0·	23·5
t Camp .	61·4	4·1	4·17	0·48	0·01	0·	12·4
urne, near n . .	131·4	5·6	4·39	0·56	0·12	0·20	26·0

e analysis of shallow well waters, drawn from a depth ian 50 feet, near human habitations, would have no l purpose in this book; as such waters are generally ed, and the analytical evidence of pollution is already with respect to deep wells, generally exceeding 100 n depth.

picious Proportions of Impurities.—Treating the fore- analysis as useful in affording some notion of pro- access of impurity either in comparatively recent or ehistoric times, it becomes necessary to draw some limits to the amount of the various constituents in le water that would justify suspicion.

	Parts per Million.		Parts per Million.
Organic Carbon . .	1·00	Nitrates	4·00
Organic Nitrogen . .	0 30	Chlorine—generally .	20·00
Albumenoid Ammonia .	0·03	Nitrites	Any
Oxygen for Total Oxidation of Organic Matter	2·00	Ammonia Saline . .	0·25

Neither the total solids nor the degree of hardness in a potable water should exceed the ordinary maximum in those of the same class and from similar strata, whether from upland surface springs or deep wells, without attracting notice.

Such limits would naturally be exceeded under special circumstances without causing suspicion, as, for instance, at places near the sea, or near salt beds, an amount of chlorine in excess of ordinary limits might be easily accounted for. It is only in connection with the local circumstances and the history of the water that any value can be attached to the indications afforded by such analyses; it should be also borne in mind that chemically pure water may be deadly, and water that is grossly impure according to the analyst may be harmless.

Suspicious Sources.—Potable waters obtained from the surface-drainage of cultivated land, from rivers or channels to which sewage may gain access, from rain-storage reservoirs or tanks, and from shallow wells, are suspicious by origin. The storage of water in an impure atmosphere, in unclean receptacles, in cisterns communicating with drain-pipes, its passage through metallic and corroded pipes, especially new-laid pipes, and old filtering material, its contact with unclean persons and things, are sufficient causes for suspecting water of any kind, however wholesome it may have been previously.

Hard Potable Waters.—The hardness of water for drinking purposes is now believed generally not to have any markedly dangerous effect on human life, so as to affect the death rates of a population; there is, however, little doubt that it is sometimes very detrimental to health.

Calculus, gravel, urinary diseases, visceral obstructions, goitre, severe dyspepsia, and constipation, are attributed to the habitual use of hard water. Soft water alone is fit for the use of the sick. The selenitic hardness due to sulphate of lime and magnesia, from the new red sandstone, and that from some shallow wells, is deemed particularly objectionable. Soft water has also its opponents in a few medical men. The belief is very prevalent that the hardness due to carbonates in drinking-water should not exceed 15° on Clark's scale.

In cooking, boiling, or making hot infusions, the economy of time, fuel, and of material, from using soft water is very marked. Soft water is also preferable for baking bread, cooking meat and vegetables, and making soups, on account of the better results obtained. In brewing, soft water is necessary for the extraction of the saccharine matter for wort. The amount of hardness suitably admissible for cooking purposes is about 5° on Clark's scale.

Hardness may be reduced by a half, that is by 50 per cent., by filtration through the spongy iron of M. Bischof; in addition the water is cleansed by the removal of a large proportion of the organic carbon and organic nitrogen, nitrites, and nitrates. When the hardness of water is due to carbonates of lime and magnesia, it may be reduced by being kept boiling for half an hour; the same treatment of any suspected water is also the best ordinary means of destroying the specific poisons of typhoid fever and cholera, against which filtration is not an efficient safeguard. The softening of water on a large scale by the addition of hydrated lime has been effectively carried out at Tring and at Canterbury, under Mr. Homersham.

The geological formations yielding hard water are the calcareous strata of the Silurian, Devonian, and carboniferous rocks, mountain limestone, new red sandstone, conglomerate sandstone, liassic, oolitic, upper green-sand, and the chalk.

The Purification of Water.—The need for purifying water

for drinking purposes might at first appear an absurdity, as the natural assumption is that moderately pure or wholesome water should be always obtained in the first instance. Under all ordinary circumstances this assumption is correct. When wholesome water can be procured within any moderate distance, the expense of bringing or delivering it is a mere trifle in comparison with the economy of human life and health effected. When an immense distance and very high expenditure enter into such undertakings, doubt is always thrown on their advisability. There is, however, a more potent cause for the habits of many civilised communities in drinking fouled or purified foul water—the power of vested interests, supported by the law of the land, which forces these habits on the people. The basis of vested interests consists in the virtue of a contract, or voluntary bargain between a community and a speculative company, by which the latter incur the large expenses of obtaining and supplying water to a town or district, and the former agree to pay certain water rates, either for a long term of years, or in perpetuity. The position of the company is that of a long leaseholder, or of a freeholder, while the town or district very often possesses no powers of repurchasing its freedom on fixed terms, and remains at the mercy of the company. The law always upholds a voluntary bargain and its results, although it may have been grossly unjust or extortionate, provided it has not taken some special form of one-sided bargain, decided by precedent to be untenable. When the precedent for annulling the bargain is wanting, the injustice is upheld by law.

The injustice of these water-companies' freehold rights consists in two points. First, under the conditions of the original contract, wholesome water existed and could be supplied in a mode practically convenient to the community, but after a long lapse of time the sources of supply became *deteriorated* from spread of habitations, and other causes

over which the company had little or no control. Eventually foul water is supplied instead of wholesome water, and it is partly purified by certain processes, as a justification for keeping up the lucrative contract with the community, and as a basis of argument in declaring the supply to be as good as it was in remote times. The bargain was to supply then existing wholesome water; immediately this becomes impracticable, the bargain should justly be considered as no longer tenable. Water companies should not be permitted to purify their water any more than milkmen are permitted to adulterate their milk; they should give an unsophisticated supply, free from any process, however harmless, or their winding-up should be enforced. Secondly, these water-companies' bargains were made with the fathers, grandfathers, or ancestry of the persons controlled; while the principle that any person or community can sell under bargain not only their own rights, but those of their seed for ever, is grossly unjust, and hence not *morally* binding on the descendants. On these grounds, such perpetuities should cease at the end of one lifetime from date of contract.

Eventually, perhaps, the law in matters of voluntary but unjust contracts may be put in closer accordance with morality. It will doubtless take some time to effect this in a mercantile speculative nation, where ninety-nine persons out of a hundred profoundly admire and uphold any systematic or permanent swindle if based on assent by document and sanctioned by legality, and where thousands owe their subsistence to such bargains made either by themselves or their forefathers. Public opinion as well as legality still countenances the grinding rack-rent that impoverishes a family, the dealer's crushing bargains with the needy artist, the benevolence of employers that patronise labour at half price. It is said that these crimes bring prosperity to the nation and are good for trade—the helpless victims are called fools. There is a legal limit to the

usurer's interest, but all other bargainers' profits are uncontrolled. All protests are equally valueless.

Things will change, but in the meantime we must drink purified foul water under compact for the prosperity of vested interests.

The modes of purifying contaminated water are the following:—

1. Simple subsidence.
2. Filtration through various materials.
3. Precipitation with various substances, acting simply as mechanical precipitants.
4. Distillation, also mere boiling.
5. Chemical treatment.
6. Irrigation, and collection of the effluent.

Some of these modes and processes are severally less or more effective in practice, according as they are carried out on a large or small scale, or the converse.

The slightest interval of neglect or bad management for an hour, or even less, may vitiate the whole of the supply: this was the case with the East London Company, at Old Ford, in 1866, resulting in the well-known cholera outbreak. Thus the lives of a large population are permanently placed at the mercy of some turncock whenever the water supply is originally foul. Similarly, also, if the domestic filtration of contaminated water be entrusted to servants, the same risks occur within a house. Such dangers should not be perpetuated.

Simple subsidence is a permissible mode of purifying any wholesome water from mud, mineral, and suspended matter. This improvement of water is incidental to storage, but it also involves frequent periodical cleansing of the vessel or reservoir in which settlement takes place: it is then a successful mode of getting rid of suspended mineral impurities of any sort.

The same method applied to contaminated waters not *only removes* mineral suspended impurities, but also slightly

reduces the amount of organic impurity, as shown in the accompanying analysis of Dr. Frankland (page 154). If, however, the persistent cleansing be neglected, it becomes a mode of collecting the impurities of several days' supply, and distributing the collection at one time.

Filtration through various materials, beds of pebbles, gravel, sand, charcoal, &c., is a mechanical mode of detaining the mineral impurities of water from passing out in the effluent. It corresponds to subsidence to a certain extent, but is hardly a permissible legitimate mode of cleansing drinking-water for a water company, as it is an artificial, and not a natural process. Companies should supply good wholesome drinking-water without resorting to any process. Filtration on a large scale is rarely performed with uniform efficiency, and the drinking-water of towns is hence generally submitted to domestic filtration. For the effect of filtration shown analytically, see page 154, where it is shown in a slight reduction of the organic impurities of contaminated water. The materials recommended by Dr. Frankland for use in domestic filters are fresh animal charcoal and Bischof's spongy iron. They both effect a large reduction of the amount of organic impurity as well as saline mineral matters; but the spongy iron also reduces the hardness of water. See two analyses selected from Dr. Frankland's results in the accompanying table.

Comparative Composition of Water Before and After Purification, in Parts per Million.

January and February, 1873.	Total Solids.	Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
West Middlesex Company.							
Thames Water from Hampton	298·4	21·8	2·76	0·53	0·09	3·46	18·0
Thames Water after Subsidence	312·2	23·3	2·09	0·71	0·05	3·29	18·0
Thames Water after Filtration	305·6	22·1	1·98	0·43	0·01	3·35	18·0
Grand Junction Company.							
Thames Water from Hampton	317·8	24·5	2·46	0·33	0·05	3·55	17·5
Thames Water after Subsidence	314·2	23·6	2·62	0·42	0·04	3·56	17·5
Thames Water after Filtration	306·8	23·3	2·31	0 32	0·01	3·45	17·5
Southwark and Vauxhall Company.							
Thames Water from Hampton	318·4	23·6	2·85	0·50	0·02	3·31	18·0
Thames Water after Subsidence	320·0	23·3	3·21	0·63	0·01	3·17	18·0
Thames Water after Filtration	315·6	23·3	2·73	0·42	0·	2·86	18·0
Lambeth Company.							
Thames Water from Molesey	313·6	23·9	3·25	0·76	0·03	3·12	17·5
Thames Water after Subsidence	329·6	23·6	2·73	0·67	0·04	3·48	18·0
Thames Water after Filtration	327·4	23·6	2·58	0·38	0·01	3·61	18·0

COMPARATIVE COMPOSITION OF WATER, &c.—*continued.*

JANUARY AND FEBRUARY, 1873.	Total Solids.	Total Hardness.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrites and Nitrates.	Chlorine.
Chelsea Company.							
Thames Water at Thames Ditton	313·6	23·9	3·25	0·76	0·03	3·12	17·5
Thames Water after Filtration .	311·0	22·7	2·58	0·32	0·	3·07	17·0
No Subsidence Reservoirs . .	..	..	..	..	..	..	..
Kent Company—Unpurified Water.							
New Well at Deptford	429·4	29·7	0·48	0·05	0·01	5·45	25·0
Bath Well at Deptford	354·4	26·6	0·44	0·07	0·	3·63	23·0
Garden Well at Deptford .	409·6	28·8	0·56	0·11	0·	3·54	24·0
Well at Shortlands .	306·4	23·9	0·21	0·07	0·	3·54	16·0
Well at Crayford .	352·0	25·7	0·31	0·05	0·	5·05	22·5
Well at Plumstead .	508·0	30·6	0·81	0·11	0·	3·38	46·0
* Well at Belvidere .	405·2	22·4	1·00	0·37	0·	20·79	33·5
* Well at Charlton .	928·0	42·6	1·39	0·28	0·	9·01	197·0
New River Company.							
Lee Water at New River intake .	344·0	25·7	2·87	0·67	0·05	3·81	18·0
New River at Hornsey Wheelhouse	329·0	24·2	3·75	0·59	0·05	3·71	17·0
New River after Subsidence and Filtration .	220·0	16·6	2·27	0·43	0·02	1·86	16·5
Unfiltered Thames Water . .	246·0	19·4	1·29	0·23	0·	1·88	16·0
Thames Water Filtered thro' Fresh Animal Charcoal	194·0	15·2	0·29	0·07	0·13	1·94	16·0
Unfiltered Thames Water . .	289·0	21·8	1·95	0·74	0·	1·23	20·0
Thames Water Filtered through Spongy Iron.	163·6	11·6	0·63	0·35	0·28	0·	20·0

* Probably now abandoned as polluted by sewage and manure.

The serious drawback to the use of animal charcoal is that it is liable to collect minute worms and favour organic life; on the other hand, though the spongy iron is perhaps the most valuable filtering material known, the renewal or replacement of it at intervals (which for cleanliness in any material should not exceed a month) might be rather costly. While the practice of filtering drinking-water in households is one much to be commended under any circumstances, it must be borne in mind that filtration is utterly powerless as a safeguard against the propagation of typhoid fever and epidemic disease through water that *has been* contaminated; and that filtration entrusted to servants is frequently a mode of rendering water more impure than before. In Oriental countries the women of the family, whether princesses or of humble rank, fetch, cool, and take care of the drinking water, a custom worthy of imitation everywhere, especially with filtered water. Correspondingly also, the men should interest themselves in the cleanliness of the cisterns and water-pipes, and their entire separation from drain-pipes, sinks, closets, gas-pipes, and all sources of impure air and foulness.

Precipitation is a mode of cleansing water by very fine powders, or substances in a minute state of division: these in their downward course under gravity carry away mechanically much of the impurities. The precipitants that have been used for this purpose are very various; it is a process which, when applied to drinking-water, is looked on with much disfavour; people say they do not want their drinking-water doctored or drugged, and dislike the risk of mistake about it.

Distillation, condensation, and boiling are modes of treating water usual only under extreme circumstances, in places where tolerably good fresh water is not to be had, or at sea, or when an epidemic is raging or has commenced. The time necessary for the water to cool, and the subsequent aëration required to make it palatable,

seem to be tedious drawbacks that militate against these methods. It may be noticed that continuous boiling for about an hour is necessary for the purification of suspected water, and though this is one of the best means known for rapidly effecting it, there is some doubt as to its invariable success.

The purification of water by mixing in it substances that effect a chemical action on the impurities is, as the use of precipitants, much disliked generally, and would never be permitted in a public service water supply. In households, the most convenient chemical method is, perhaps, the addition of a small pinch of permanganate of potash to a large jugful of water, and leaving it for a few hours to act before drinking.

Irrigation is the natural correct mode of employing contaminated water: it utilises the organic impurities in fertilising land, and favours the growth of crops. The effluent water from any sort of irrigation as well as that from cultivated manured land, under special management, intermittent action, and deep under-drainage, may be rendered very clean, and useful for many purposes, as washing-water and flushing-water (*see* page 160). It should not be used as drinking-water, however pure it may be, and however low the organic impurities may be (in this respect it is often better than filtered Thames water), on account of the exclusively animal origin of such impurities; but it certainly ranks above shallow well water.

Washing-Water.—The purity of water for personal washing, bathing, lavatories, and laundry-work is a subject on which very little attention has been bestowed; its softness from economic considerations being thought a more important quality. While it may be admitted that water for external application need not be so pure or wholesome as drinking-water, there should yet be some limit to its impurity. Certain substances are poisons when applie

by way of cataplasm to the external skin; certain diseases may be transferred through any slight abrasion or scratch, and it is difficult to say how much or how little dilution would prevent virus from taking effect either in hand-washing or bathing, or by transfer through the washing of linen to be worn next to the skin for a certain time As to sewage impurities, the few cases in which persons have taken an involuntary partial bath in simple fresh sewage have indicated that no ill effect results; but it might be otherwise with either putrescent sewage, or sewage from diseased patients. The partly oxidised residues from sewage may also have no ill effect, while ammoniacal residues, far from doing harm, would probably aid in cleansing the skin, and in the removal of greasy matters from linen.

As to organic impurities due to putrescent vegetable matter, there is no evidence attainable in England; but if we look to other countries there are strong indications of poisonous and semi-poisonous effects due to personal contact with water containing them either in suspension or in solution. In some tracts of country in South America there is literally nothing but forest and marsh, rivers and lagoons, for hundreds of miles. Not a single inhabitant; even wild animals are scarce; no mines, or chance of mineral poison; the contamination of water is purely of vegetable origin; yet a mere partial wetting of the body, without immediate wiping dry, produces fever, and a soaking, or total immersion in the water, produces such severe fever as to result in death in many, if not in most, cases. Not only the lagoons but the running streams and rivers possess this quality. It is well known there that immediate rubbing dry renders even an immersion harmless; but towels are not always available on a journey. Such effects cannot be attributable to chill, as *the climate* is hot, and the sun will dry one very rapidly.

The conclusion seems inevitable that putrescent organic

impurities of vegetable origin are generally poisonous when applied to the skin and allowed to remain there. It might be urged that in such a country where strong vegetable poisons exist, where the manzanilla produces attacks resembling epilepsy, and may cause death to those that merely remain within its influence; where the scratch from a passing bough of more than one tree will cause fearfu swelling of the whole head, and endanger life—the before-mentioned effects may be due to some special poison. The wide-spread cases, known and observed, are opposed to this view; while the additional fact, that in the same districts the mosquitos, gnats, and water-insects of many varieties, have a corresponding power of causing fever and in some cases death, supports the conclusion before given.

If this deduction is generally correct, one of the chief objects of analysis of washing-water should be the determination of the organic vegetable impurities, and the production of evidence of their existence in various stages of putrescence and oxidation; while in Dr. Frankland's analytical results, the proportion and amount of organic carbon is the sole and very untrustworthy guide. If the deduction is not correct, the only remaining alternative is to suppose the impurities in the South American waters to be due to a special type of putrescent organic matter from swarms of dead insects and animalcules. In either case the effect on bathing-water is important from its indications.

The impurity of water used in laundry-work, and consequent ill-effects—transmitted contagion, &c.—are also matters yet uninvestigated. The use of caustic alkalis—and other things that destroy linen—is often deemed sufficient preservative against all impurities in the excessively filthy water used in London laundries, more especially by French laundresses, or bleachers. But this idea is not correct, for Dr. Frankland's analyses of Thames water, before and after using Clark's caustic-lime process, show that on the average the organic carbon is

reduced by only one-third, and the organic nitrogen is sometimes diminished and sometimes increased. (See page 215 of Sixth Report.) Of the enormous economy in soap resulting from using soft water there is no doubt, nor is there any doubt that Clark's caustic-lime method is the cheapest way of removing temporary hardness from water; but such operations are best carried out by water companies on a large scale, as at Tring, Canterbury, and Caterham. The limits of hardness usual for water used in washing are from 3 to 7 degrees.

The geological formations generally yielding soft water are the igneous, metamorphic, and Cambrian rocks; the non-calcareous, Silurian, Devonian, and carboniferous strata; the millstone grit, lower green-sand, London and Oxford clay, Bagshot beds, and non-calcareous gravel.

See also hardness of potable waters at page 148.

Flushing Water.—The water employed in scrubbing floors, washing buildings, watering streets, and flushing latrines, urinals, and drains, is generally supposed to be of a sort requiring but little purity. It certainly need not be pure as washing-water for personal purposes, yet its purity is not a matter of indifference. Any impurities it may have are spread over large areas—the interiors of dwelling-houses and the whole roadway of all the streets. The water evaporates or runs off, the impurities are wafted by the wind or the draught, and a certain proportion of them must reach the lungs of the people. Hence the need of some reasonable limit to the contamination even of such water.

Water for Horse-Troughs, Cattle-Ponds, &c.—As the horse, and more especially the well-bred horse, is an animal possessing high discriminating sense with regard to good drinking-water, and seems to be fully aware that his digestion suffers from both bad water and hard water, the limits of purity and hardness are best determined by his choice. *Horned cattle,* sheep, and many other animals, seem to be

comparatively indifferent as to the quality of the water they drink.

Factory and Boiler Water.—The water for use in some of the industrial arts and manufactures, in some branches of dyeing, in brewing, require both a high degree of purity and a low grade of hardness; in others, almost any water will answer the required purpose. The special requirements and conditions have therefore to be studied in each case. Brewers generally require two sorts of water—one hard, the other soft. The water for boilers of factories and steam-engines should have a low grade of hardness, not exceeding five, so as to prevent incrustation, which, in some cases, might cause absolute danger.

Irrigation Water.—The water used in irrigation has to be suited both to the crop grown and to the soil irrigated; its value is dependent on its fertilising qualities or manurial constituents. (See Analysis, on page 136, of the Water of the Nile.) The organic impurities objectionable in drinking-water are useful in irrigation water. It must not, however, be imagined that all town refuse can be usefully employed in irrigation even on a sewage farm: the road grit, flints, foul cinders, gravel, broken kettles and old sheets of corrugated iron, smashed china, and many other things, add nothing to the fertility of the soil or the growth of crops. Even where the town drainage consists of simple sewage, much of this even is inert matter: the ammonia, nitrates, phosphates, and alkaline silicates are the principal manurial constituents of value, and the fresh urine, applied to the soil before putrescence or extreme dilution, is the most useful part, by bulk, in town refuse. The control of the supply of irrigation water, whether manurial or not, must be left entirely in the hands of the farmer. He cannot be expected to flood his fields with storm water or cover them with refuse, regardless of the effect on the crop or the soil. The periods of intermission must be determined by him, not by municipal officials, that are merely interested in

getting rid of their refuse. For further information on the use and application of irrigation water, see articles on "The Watering of Land and on the Drainage of Fields," in Chapter III., "Hydraulic Manual," fourth edition, Lockwood, 1883.

L. J.

INDEX.

THE END.

PRINTED BY J. S. VIRTUE AND CO., LIMITED, CITY ROAD, LONDON.

WEALE'S RUDIMENTARY SCIENTIFIC SERIES.

*** The volumes of this Series are freely Illustrated with Woodcuts, or otherwise, where requisite. Throughout the following List it must be understood that the books are bound in limp cloth, unless otherwise stated; *but the volumes marked with a ‡ may also be had strongly bound in cloth boards for 6d. extra.*

N.B.—In ordering from this List it is recommended, as a means of facilitating business and obviating error, to quote the numbers affixed to the volumes, as well as the titles and prices.

No. ARCHITECTURE, BUILDING, ETC.

16. *ARCHITECTURE—ORDERS*—The Orders and their Æsthetic Principles. By W. H. LEEDS. Illustrated. 1s. 6d.

17. *ARCHITECTURE—STYLES*—The History and Description of the Styles of Architecture of Various Countries, from the Earliest to the Present Period. By T. TALBOT BURY, F.R.I.B.A., &c. Illustrated. 2s.
*** ORDERS AND STYLES OF ARCHITECTURE, *in One Vol.*, 3s. 6d.

18. *ARCHITECTURE—DESIGN*—The Principles of Design in Architecture, as deducible from Nature and exemplified in the Works of the Greek and Gothic Architects. By E. L. GARBETT, Architect. Illustrated. 2s. 6d.

*** *The three preceding Works, in One handsome Vol., half bound, entitled* "MODERN ARCHITECTURE," *price* 6s.

22. *THE ART OF BUILDING*, Rudiments of. General Principles of Construction, Materials used in Building, Strength and Use of Materials, Working Drawings, Specifications, and Estimates. By E. DOBSON, 2s.‡

23. *BRICKS AND TILES*, Rudimentary Treatise on the Manufacture of; containing an Outline of the Principles of Brickmaking. By EDW. DOBSON, M.R.I.B.A. With Additions by C. TOMLINSON, F.R.S. Illustrated, 3s.‡

25. *MASONRY AND STONECUTTING;* in which the Principles of Masonic Projection and their application to the Construction of Curved Wing-Walls, Domes, Oblique Bridges, and Roman and Gothic Vaulting, are explained. By EDWARD DOBSON, M.R.I.B.A., &c. 2s. 6d.‡

44. *FOUNDATIONS AND CONCRETE WORKS*, a Rudimentary Treatise on; containing a Synopsis of the principal cases of Foundation Works, with the usual Modes of Treatment, and Practical Remarks on Footings, Planking, Sand, Concrete, Béton, Pile-driving, Caissons, and Cofferdams. By E. DOBSON, M.R.I.B.A., &c. Fifth Edition, revised. 1s. 6d.

42. *COTTAGE BUILDING.* By C. BRUCE ALLEN, Architect. Ninth Edition, revised and enlarged. Numerous Illustrations. 1s. 6d.

45. *LIMES, CEMENTS, MORTARS, CONCRETES, MASTICS,* PLASTERING, &c. By G. R. BURNELL, C.E. Twelfth Edition. 1s. 6d.

57. *WARMING AND VENTILATION*, a Rudimentary Treatise on; being a concise Exposition of the General Principles of the Art of Warming and Ventilating Domestic and Public Buildings, Mines, Lighthouses, Ships, &c. By CHARLES TOMLINSON, F.R.S., &c. Illustrated. 3s.

83**. *CONSTRUCTION OF DOOR LOCKS.* Compiled from the Papers of A. C. HOBBS, Esq., of New York, and Edited by CHARLES TOMLINSON, F.R.S. To which is added, a Description of Fenby's Patent Locks, and a Note upon IRON SAFES by ROBERT MALLET, M.I.C.E. Illus. 2s. 6d.

111. *ARCHES, PIERS, BUTTRESSES, &c.:* Experimental Essays on the Principles of Construction in; made with a view to their being useful to the Practical Builder. By WILLIAM BLAND. Illustrated. 1s. 6d.

116. *THE ACOUSTICS OF PUBLIC BUILDINGS;* or, The Principles of the Science of Sound applied to the purposes of the Architect and Builder. By T. ROGER SMITH, M.R.I.B.A., Architect. Illustrated. 1s. 6d.

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

Architecture, Building, etc., ***continued.***

127. *ARCHITECTURAL MODELLING IN PAPER*, the Art of. By T. A. RICHARDSON, Architect. Illustrated. 1s. 6d.

128. *VITRUVIUS—THE ARCHITECTURE OF MARCUS VITRUVIUS POLLO.* In Ten Books. Translated from the Latin by JOSEPH GWILT, F.S.A., F.R.A.S. With 23 Plates. 5s.

130. *GRECIAN ARCHITECTURE*, An Inquiry into the Principles of Beauty in; with an Historical View of the Rise and Progress of the Art in Greece. By the EARL OF ABERDEEN. 1s.

*** *The two preceding Works in One handsome Vol., half bound, entitled* "ANCIENT ARCHITECTURE," *price* 6s.

132. *DWELLING-HOUSES*, a Rudimentary Treatise on the Erection of. Illustrated by a Perspective View, Plans, Elevations, and Sections of a pair of Semi-detached Villas, with the Specification, Quantities, and Estimates, and every requisite detail, in sequence, for their Construction and Finishing. By S. H. BROOKS, Architect. New Edition, with Plates. 2s. 6d.‡

156. *QUANTITIES AND MEASUREMENTS*, How to Calculate and Take them in Bricklayers', Masons', Plasterers', Plumbers', Painters', Paper-hangers', Gilders', Smiths', Carpenters', and Joiners' Work. By A. C. BEATON, Architect and Surveyor. New and Enlarged Edition. Illus. 1s. 6d.

175. *LOCKWOOD & CO.'S BUILDER'S AND CONTRACTOR'S* PRICE BOOK, for 1883, containing the latest Prices of all kinds of Builders' Materials and Labour, and of all Trades connected with Building, &c., &c. Revised and Edited by F. T. W. MILLER, Architect and Surveyor. 3s. 6d.; half bound, 4s. [*Just published.*

182. *CARPENTRY AND JOINERY*—THE ELEMENTARY PRINCIPLES OF CARPENTRY. Chiefly composed from the Standard Work of THOMAS TREDGOLD, C.E With Additions from the Works of the most Recent Authorities, and a TREATISE ON JOINERY by E. WYNDHAM TARN, M.A. Numerous Illustrations. 3s. 6d.‡

182*. *CARPENTRY AND JOINERY. ATLAS* of 35 Plates to accompany the above. With Descriptive Letterpress. 4to. 6s.; cloth, 7s. 6d.

187. *HINTS TO YOUNG ARCHITECTS.* By GEORGE WIGHTWICK. New, Revised, and enlarged Edition. By G. HUSKISSON GUILLAUME, Architect. With numerous Woodcuts. 3s. 6d.‡

188. *HOUSE PAINTING, GRAINING, MARBLING, AND SIGN WRITING:* A Practical Manual of, containing full information on the Processes of House-Painting, the Formation of Letters and Practice of Sign-Writing, the Principles of Decorative Art, a Course of Elementary Drawing for House-Painters, Writers, &c., &c. With 9 Coloured Plates of Woods and Marbles, and nearly 150 Wood Engravings. By ELLIS A. DAVIDSON. Third Edition, revised. 5s. cloth limp; 6s. cloth boards.

189. *THE RUDIMENTS OF PRACTICAL BRICKLAYING.* In Six Sections: General Principles; Arch Drawing, Cutting, and Setting; Pointing; Paving, Tiling, Materials; Slating and Plastering; Practical Geometry, Mensuration, &c. By ADAM HAMMOND. Illustrated. 1s. 6d.

191. *PLUMBING.* A Text-Book to the Practice of the Art or Craft of the Plumber. With Chapters upon House Drainage, embodying the latest Improvements. Fourth Edition, revised and enlarged. With above 330 Illustrations. By W. P. BUCHAN, Sanitary Engineer. 3s. 6d.‡ [*Just published.*

192. *THE TIMBER IMPORTER'S, TIMBER MERCHANT'S,* and BUILDER'S STANDARD GUIDE; comprising copious and valuable Memoranda for the Retailer and Builder. By RICHARD E. GRANDY. Second Edition, Revised. 3s.‡

205. *THE ART OF LETTER PAINTING MADE EASY.* By J. G. BADENOCH. Illustrated with 12 full-page Engravings of Examples. 1s.

206. *A BOOK ON BUILDING, Civil and Ecclesiastical,* including CHURCH RESTORATION. With the Theory of Domes and the Great Pyramid, &c. By Sir EDMUND BECKETT, Bart., LL.D., Q.C., F.R.A.S. Second Edition, enlarged, 4s. 6d.‡

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

Architecture, Building, etc., *continued.*

226. *THE JOINTS MADE AND USED BY BUILDERS* in the Construction of various kinds of Engineering and Architectural Works (A Practical Treatise on). With especial reference to those wrought by Artificers in Erecting and Finishing Habitable Structures. By WYVILL J. CHRISTY, Architect. With upwards of 160 Engravings on Wood. 3s.‡

228. *THE CONSTRUCTION OF ROOFS OF WOOD AND IRON* (An Elementary Treatise on). Deduced chiefly from the Works of Robison, Tredgold, and Humber. By E. WYNDHAM TARN, M.A., Architect. With numerous Illustrations. 1s. 6d. [*Just published.*

229. *ELEMENTARY DECORATION:* A Guide to the Simpler Forms of Everyday Art, as applied to the Interior and Exterior Decoration of Dwelling-Houses, &c. By JAMES W. FACEY, Jun. Illustrated with Sixty-eight explanatory Engravings, principally from Designs by the Author. 2s. [*Just published.*

230. *HANDRAILING* (A Practical Treatise on). Showing New and Simple Methods for finding the Pitch of the Plank, Drawing the Moulds, Bevelling, Jointing-up, and Squaring the Wreath. By GEORGE COLLINGS. Illustrated with Plates and Diagrams. 1s. 6d. [*Just published.*

CIVIL ENGINEERING, ETC.

219. *CIVIL ENGINEERING.* By HENRY LAW, M.Inst. C.E. Including a Treatise on HYDRAULIC ENGINEERING by GEO. R. BURNELL, M.Inst.C.E. Sixth Edition, revised, WITH LARGE ADDITIONS ON RECENT PRACTICE IN CIVIL ENGINEERING, by D. KINNEAR CLARK, M.Inst. C.E., Author of "Tramways: Their Construction," &c. 6s. 6d., Cloth boards, 7s. 6d.

31. *WELL-DIGGING, BORING, AND PUMP-WORK.* By JOHN GEORGE SWINDELL, A.R.I.B.A. New Edition, by G. R. BURNELL, C.E. 1s. 6d.

35. *THE BLASTING AND QUARRYING OF STONE,* for Building and other Purposes. With Remarks on the Blowing up of Bridges. By Gen. Sir JOHN BURGOYNE, Bart., K.C.B. Illustrated. 1s. 6d.

62. *RAILWAY CONSTRUCTION,* Elementary and Practical Instructions on the Science of. By Sir M. STEPHENSON, C.E. New Edition, by EDWARD NUGENT, C.E. With Statistics of the Capital, Dividends, and Working of Railways in the United Kingdom. By E. D. CHATTAWAY. 4s.

80*. *EMBANKING LANDS FROM THE SEA,* the Practice of. Treated as a Means of Profitable Employment for Capital. With Examples and Particulars of actual Embankments, &c. By J. WIGGINS, F.G.S. 2s.

81. *WATER WORKS,* for the Supply of Cities and Towns. With a Description of the Principal Geological Formations of England as influencing Supplies of Water; and Details of Engines and Pumping Machinery for raising Water. By SAMUEL HUGHES, F.G.S., C.E. New Edition. 4s.‡

117. *SUBTERRANEOUS SURVEYING,* an Elementary and Practical Treatise on. By THOMAS FENWICK. Also the Method of Conducting Subterraneous Surveys without the Use of the Magnetic Needle, and other Modern Improvements. By THOMAS BAKER, C.E. Illustrated. 2s. 6d.‡

118. *CIVIL ENGINEERING IN NORTH AMERICA,* a Sketch of. By DAVID STEVENSON, F.R.S.E., &c. Plates and Diagrams. 3s.

197. *ROADS AND STREETS (THE CONSTRUCTION OF),* in two Parts: I. THE ART OF CONSTRUCTING COMMON ROADS, by HENRY LAW, C.E., revised by D. K. CLARK, C.E.; II. RECENT PRACTICE, including pavements of Stone, Wood, and Asphalte, by D. K. CLARK. 4s. 6d.‡

203. *SANITARY WORK IN THE SMALLER TOWNS AND IN VILLAGES.* Comprising:—1. Some of the more Common Forms of Nuisance and their Remedies; 2. Drainage; 3. Water Supply. By CHARLES SLAGG, A.I.C.E. 2s. 6d.‡

212. *THE CONSTRUCTION OF GAS-WORKS,* and the Manufacture and Distribution of Coal Gas. Originally written by SAMUEL HUGHES, C.E. Sixth Edition, re-written and much Enlarged by WILLIAM RICHARDS, C.E. With 72 Illustrations. 4s. 6d.‡

213. *PIONEER ENGINEERING.* A Treatise on the Engineering Operations connected with the Settlement of Waste Lands in New Countries. By EDWARD DOBSON, Assoc. Inst. C.E. 4s. 6d.‡

☞ ***The ‡ indicates that these vols. may be had strongly bound at 6d. extra.***

MECHANICAL ENGINEERING, ETC.

33. *CRANES*, the Construction of, and other Machinery for Raising Heavy Bodies. By JOSEPH GLYNN, F.R.S. Illustrated. 1s. 6d.
34. *THE STEAM ENGINE.* By Dr. LARDNER. Illustrated. 1s. 6d.
59. *STEAM BOILERS:* their Construction and Management. By R. ARMSTRONG, C.E. Illustrated. 1s. 6d.
67. *CLOCKS, WATCHES, AND BELLS*, a Rudimentary Treatise on. By Sir EDMUND BECKETT, LL.D., Q.C. Seventh Edition, revised and enlarged, with numerous Illustrations. 4s. 6d. cloth limp; 5s. 6d. cloth boards. [*Just published.*
82. *THE POWER OF WATER*, as applied to drive Flour Mills, and to give motion to Turbines, &c. By JOSEPH GLYNN, F.R.S. 2s.‡
98. *PRACTICAL MECHANISM*, the Elements of; and Machine Tools. By T. BAKER, C.E. With Additions by J. NASMYTH, C.E. 2s. 6d.‡
139. *THE STEAM ENGINE*, a Treatise on the Mathematical Theory of, with Rules and Examples for Practical Men. By T. BAKER, C.E. 1s. 6d.
162. *THE BRASS FOUNDER'S MANUAL;* Instructions for Modelling, Pattern-Making, Moulding, Turning, Filing, Burnishing, Bronzing, &c. With copious Receipts, &c. By WALTER GRAHAM. 2s.‡
164. *MODERN WORKSHOP PRACTICE*, as applied to Marine, Land, and Locomotive Engines, Floating Docks, Dredging Machines, Bridges, Cranes, Ship-building, &c., &c. By J. G. WINTON. Illustrated. 3s.‡
165. *IRON AND HEAT*, exhibiting the Principles concerned in the Construction of Iron Beams, Pillars, and Bridge Girders, and the Action of Heat in the Smelting Furnace. By J. ARMOUR, C.E. 2s. 6d.‡
166. *POWER IN MOTION:* Horse-Power, Toothed-Wheel Gearing, Long and Short Driving Bands, and Angular Forces. By J. ARMOUR, 2s. 6d.‡
167. *IRON BRIDGES, GIRDERS, ROOFS, AND OTHER* WORKS. By FRANCIS CAMPIN, C.E. 2s. 6d.‡
171. *THE WORKMAN'S MANUAL OF ENGINEERING* DRAWING. By JOHN MAXTON, Engineer. Fourth Edition. Illustrated with 7 Plates and nearly 350 Woodcuts. 3s. 6d.‡
190. *STEAM AND THE STEAM ENGINE*, Stationary and Portable. Being an extension of Mr. John Sewell's "Treatise on Steam." By D. K. CLARK, M.I.C.E. Second Edition, revised. 3s. 6d.‡
200. *FUEL*, its Combustion and Economy. By C. W. WILLIAMS, A.I.C.E. With extensive additions on Recent Practice in the Combustion and Economy of Fuel—Coal, Coke, Wood, Peat, Petroleum, &c.—by D. K. CLARK, M.I.C.E. 2nd Edition. 3s. 6d.‡
202. *LOCOMOTIVE ENGINES.* By G. D. DEMPSEY, C.E.; with large additions by D. KINNEAR CLARK, M.I.C.E. 3s.‡
211. *THE BOILERMAKER'S ASSISTANT* in Drawing, Templating, and Calculating Boiler and Tank Work. By JOHN COURTNEY, Practical Boiler Maker. Edited by D. K. CLARK, C.E. 100 Illustrations. 2s.
216. *MATERIALS AND CONSTRUCTION;* A Theoretical and Practical Treatise on the Strains, Designing, and Erection of Works of Construction. By FRANCIS CAMPIN, C.E. 3s.‡
217. *SEWING MACHINERY:* Its Construction, History, &c., with full Technical Directions for Adjusting, &c. By J. W. URQUHART, C.E. 2s.‡
223. *MECHANICAL ENGINEERING.* Comprising Metallurgy, Moulding, Casting, Forging, Tools, Workshop Machinery, Manufacture of the Steam Engine, &c. By FRANCIS CAMPIN, C.E. 2s. 6d.‡
224. *COACH BUILDING*, A Practical Treatise, Historical and Descriptive. By J. W. BURGESS. 2s. 6d.‡
235. *PRACTICAL ORGAN BUILDING.* By W. E. DICKSON, M.A., Precentor of Ely Cathedral. Illustrated. 2s. 6d.‡ [*Just published.*
236. *DETAILS OF MACHINERY.* Comprising Instructions for the Execution of various Works in Iron in the Fitting-Shop, Foundry, and Boiler-Yard. Arranged expressly for the use of Draughtsmen, Students, and Foremen Engineers. By FRANCIS CAMPIN, C.E. 3s.‡ [*Just published.*

THE SMITHY AND FORGE; including the Farrier's Art and Coach Smithing. By W. J. E. CRANE. Illustrated. [*In the press.*

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

SHIPBUILDING, NAVIGATION, MARINE ENGINEERING, ETC.

51. *NAVAL ARCHITECTURE*, the Rudiments of; or an Exposition of the Elementary Principles of the Science, and their Practical Application to Naval Construction. Compiled for the Use of Beginners. By JAMES PEAKE, School of Naval Architecture, H.M. Dockyard, Portsmouth. Fourth Edition, corrected, with Plates and Diagrams. 3s. 6d.‡

53*. *SHIPS FOR OCEAN AND RIVER SERVICE*, Elementary and Practical Principles of the Construction of. By HAKON A. SOMMERFELDT, Surveyor of the Royal Norwegian Navy. With an Appendix. 1s. 6d.

53**. *AN ATLAS OF ENGRAVINGS* to Illustrate the above. Twelve large folding plates. Royal 4to, cloth. 7s. 6d.

54. *MASTING, MAST-MAKING, AND RIGGING OF SHIPS*, Rudimentary Treatise on. Also Tables of Spars, Rigging, Blocks; Chain, Wire, and Hemp Ropes, &c., relative to every class of vessels. With an Appendix of Dimensions of Masts and Yards of the Royal Navy. By ROBERT KIPPING, N.A. Fourteenth Edition. Illustrated. 2s.‡

54*. *IRON SHIP-BUILDING*. With Practical Examples and Details for the Use of Ship Owners and Ship Builders. By JOHN GRANTHAM, Consulting Engineer and Naval Architect. 5th Edition, with Additions. 4s.

54**. *AN ATLAS OF FORTY PLATES* to Illustrate the above. Fifth Edition. Including the latest Examples, such as H.M. Steam Frigates "Warrior," "Hercules," "Bellerophon;" H.M. Troop Ship "Serapis," Iron Floating Dock, &c., &c. 4to, boards. 38s.

55. *THE SAILOR'S SEA BOOK:* a Rudimentary Treatise on Navigation. Part I. How to Keep the Log and Work it off. Part II. On Finding the Latitude and Longitude. By JAMES GREENWOOD, B.A. To which are added, the Deviation and Error of the Compass; Great Circle Sailing; the International (Commercial) Code of Signals; the Rule of the Road at Sea; Rocket and Mortar Apparatus for Saving Life; the Law of Storms; and a Brief Dictionary of Sea Terms. With numerous Woodcuts and Coloured Plates of Flags. New, thoroughly revised and much enlarged edition. By W. H. ROSSER. 2s. 6d.‡

80. *MARINE ENGINES, AND STEAM VESSELS*, a Treatise on. Together with Practical Remarks on the Screw and Propelling Power, as used in the Royal and Merchant Navy. By ROBERT MURRAY, C.E., Engineer-Surveyor to the Board of Trade. With a Glossary of Technical Terms, and their Equivalents in French, German, and Spanish. Seventh Edition, revised and enlarged. Illustrated. 3s.‡

83*bis*. *THE FORMS OF SHIPS AND BOATS:* Hints, Experimentally Derived, on some of the Principles regulating Ship-building. By W. BLAND. Seventh Edition, revised, with numerous Illustrations and Models. 1s. 6d.

99. *NAVIGATION AND NAUTICAL ASTRONOMY*, in Theory and Practice. By Professor J. R. YOUNG. New Edition, including the requisite Elements from the Nautical Almanac for working the Problems. Illustrated. 2s. 6d. [*Just published.*

100*. *TABLES* intended to facilitate the Operations of Navigation and Nautical Astronomy, as an Accompaniment to the above Book. By J. R. YOUNG. 1s. 6d.

106. *SHIPS' ANCHORS*, a Treatise on. By G. COTSELL, N.A. 1s. 6d.

149. *SAILS AND SAIL-MAKING*, an Elementary Treatise on. With Draughting, and the Centre of Effort of the Sails. Also, Weights and Sizes of Ropes; Masting, Rigging, and Sails of Steam Vessels, &c., &c. Eleventh Edition, enlarged, with an Appendix. By ROBERT KIPPING, N.A., Sailmaker, Quayside, Newcastle. Illustrated. 2s. 6d.‡

155. *THE ENGINEER'S GUIDE TO THE ROYAL AND* MERCANTILE NAVIES. By a PRACTICAL ENGINEER. Revised by D. F. M'CARTHY, late of the Ordnance Survey Office, Southampton. 3s.

55 & 204. *PRACTICAL NAVIGATION*. Consisting of The Sailor's Sea-Book. By JAMES GREENWOOD and W. H. ROSSER. Together with the requisite Mathematical and Nautical Tables for the Working of the Problems. By HENRY LAW, C.E., and J. R. YOUNG, formerly Professor of Mathematics in Belfast College. Illustrated with numerous Wood Engravings and Coloured Plates. 7s. Strongly half-bound in leather.

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

PHYSICAL SCIENCE, NATURAL PHILOSOPHY, ETC.

1. *CHEMISTRY*, for the Use of Beginners. By Professor GEORGE FOWNES, F.R.S. With an Appendix on the Application of Chemistry to Agriculture. 1s.

2. *NATURAL PHILOSOPHY*, Introduction to the Study of; for the Use of Beginners. By C. TOMLINSON, Lecturer on Natural Science in King's College School, London. Woodcuts. 1s. 6d.

4. *MINERALOGY*, Rudiments of; a concise View of the Properties of Minerals. By A. RAMSAY, Jun. Woodcuts and Steel Plates. 3s.‡

6. *MECHANICS*, Rudimentary Treatise on; being a concise Exposition of the General Principles of Mechanical Science, and their Applications. By CHARLES TOMLINSON. Illustrated. 1s. 6d.

7. *ELECTRICITY;* showing the General Principles of Electrical Science, and the purposes to which it has been applied. By Sir W. SNOW HARRIS, F.R.S., &c. With Additions by R. SABINE, C.E., F.S.A. 1s. 6d.

7*. *GALVANISM*, Rudimentary Treatise on, and the General Principles of Animal and Voltaic Electricity. By Sir W. SNOW HARRIS. New Edition, with considerable Additions by ROBERT SABINE, C.E., F.S A. 1s. 6d.

8. *MAGNETISM;* being a concise Exposition of the General Principles of Magnetical Science, and the Purposes to which it has been applied. By Sir W. SNOW HARRIS. New Edition, revised and enlarged by H. M. NOAD, Ph.D., Vice-President of the Chemical Society, Author of "A Manual of Electricity," &c., &c. With 165 Woodcuts. 3s. 6d.‡

11. *THE ELECTRIC TELEGRAPH;* its History and Progress; with Descriptions of some of the Apparatus. By R. SABINE, C.E., F.S.A. 3s.

12. *PNEUMATICS*, for the Use of Beginners. By CHARLES TOMLINSON. Illustrated. 1s. 6d.

72. *MANUAL OF THE MOLLUSCA;* a Treatise on Recent and Fossil Shells. By Dr. S. P. WOODWARD, A.L.S. Fourth Edition. With Appendix by RALPH TATE, A.L.S., F.G.S. With numerous Plates and 300 Woodcuts. 6s. 6d. Cloth boards, 7s. 6d.

79**. *PHOTOGRAPHY*, Popular Treatise on; with a Description of the Stereoscope, &c. Translated from the French of D. VAN MONCKHOVEN, by W. H. THORNTHWAITE, Ph.D. Woodcuts. 1s. 6d.

96. *ASTRONOMY.* By the late Rev. ROBERT MAIN, M.A., F.R.S., formerly Radcliffe Observer at Oxford. Third Edition, revised and corrected to the Present Time. By WILLIAM THYNNE LYNN, B.A., F.R.A.S., formerly of the Royal Observatory, Greenwich. 2s. [*Just published.*

97. *STATICS AND DYNAMICS*, the Principles and Practice of; embracing also a clear development of Hydrostatics, Hydrodynamics, and Central Forces. By T. BAKER, C.E. 1s. 6d.

138. *TELEGRAPH*, Handbook of the; a Manual of Telegraphy, Telegraph Clerks' Remembrancer, and Guide to Candidates for Employment in the Telegraph Service. By R. BOND. Fourth Edition, revised and enlarged: to which is appended, QUESTIONS on MAGNETISM, ELECTRICITY, and PRACTICAL TELEGRAPHY, for the Use of Students, by W. MCGREGOR, First Assistant Supnt., Indian Gov. Telegraphs. 3s.‡

173. *PHYSICAL GEOLOGY*, partly based on Major-General PORTLOCK'S "Rudiments of Geology." By RALPH TATE, A.L.S., &c. Woodcuts. 2s.

174. *HISTORICAL GEOLOGY*, partly based on Major-General PORTLOCK'S "Rudiments." By RALPH TATE, A.L.S., &c. Woodcuts. 2s. 6d.

173 & 174. *RUDIMENTARY TREATISE ON GEOLOGY*, Physical and Historical. Partly based on Major-General PORTLOCK'S "Rudiments of Geology." By RALPH TATE, A.L.S., F.G.S., &c. In One Volume. 4s. 6d.‡

183 & 184. *ANIMAL PHYSICS*, Handbook of. By Dr. LARDNER, D.C.L., formerly Professor of Natural Philosophy and Astronomy in University College, Lond. With 520 Illustrations. In One Vol. 7s. 6d., cloth boards.

*** *Sold also in Two Parts, as follows :—*

183. ANIMAL PHYSICS. By Dr. LARDNER. Part I., Chapters I.—VII. 4s.
184. ANIMAL PHYSICS. By Dr. LARDNER. Part II., Chapters VIII.—XVIII. 3s.

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

MINING, METALLURGY, ETC.

117. *SUBTERRANEOUS SURVEYING*, Elementary and Practical Treatise on, with and without the Magnetic Needle. By THOMAS FENWICK, Surveyor of Mines, and THOMAS BAKER, C.E. Illustrated. 2s. 6d.‡

133. *METALLURGY OF COPPER ;* an Introduction to the Methods of Seeking, Mining, and Assaying Copper, and Manufacturing its Alloys. By ROBERT H. LAMBORN, Ph.D. Woodcuts. 2s. 6d.‡

134. *METALLURGY OF SILVER AND LEAD.* By Dr. R. H. LAMBORN. Woodcuts. 2s. 6d.‡

135. *ELECTRO-METALLURGY;* Practically Treated. By ALEXANDER WATT, F.R.S.S.A. 7th Edition, revised, with important additions, including the Electro-Deposition of Nickel, &c. Woodcuts. 3s.‡

172. *MINING TOOLS*, Manual of. For the Use of Mine Managers, Agents, Students, &c. By WILLIAM MORGANS. 2s. 6d.‡

172*. *MINING TOOLS, ATLAS* of Engravings to Illustrate the above, containing 235 Illustrations, drawn to Scale. 4to. 4s. 6d.; cloth boards, 6s.

176. *METALLURGY OF IRON.* Containing History of Iron Manufacture. Methods of Assay, and Analyses of Iron Ores, Processes of Manufacture of Iron and Steel, &c. By H. BAUERMAN, F.G.S. 5th Edition, revised and enlarged. 5s.‡ [*Just published.*

180. *COAL AND COAL MINING*, A Rudimentary Treatise on. By WARINGTON W. SMYTH, M.A., F.R.S. Fifth Edition, revised and enlarged. With numerous Illustrations. 3s. 6d.‡

195. *THE MINERAL SURVEYOR AND VALUER'S COMPLETE GUIDE*, with new Traverse Tables, and Descriptions of Improved Instruments; also the Correct Principles of Laying out and Valuing Mineral Properties. By WILLIAM LINTERN, Mining and Civil Engineer. 3s. 6d.‡

214. *SLATE AND SLATE QUARRYING*, Scientific, Practical, and Commercial. By D. C. DAVIES, F.G.S., Mining Engineer, &c. With numerous Illustrations and Folding Plates. 3s.‡

215. *THE GOLDSMITH'S HANDBOOK*, containing full Instructions for the Alloying and Working of Gold. By GEORGE E. GEE, Goldsmith and Silversmith. Second Edition, considerably enlarged. 3s.‡

225. *THE SILVERSMITH'S HANDBOOK*, containing full Instructions for the Alloying and Working of Silver. By GEORGE E. GEE. 3s.‡

220. *MAGNETIC SURVEYING, AND ANGULAR SURVEYING*, with Records of the Peculiarities of Needle Disturbances. Compiled from the Results of carefully made Experiments. By WILLIAM LINTERN, Mining and Civil Engineer and Surveyor. 2s.

FINE ARTS.

20. *PERSPECTIVE FOR BEGINNERS.* Adapted to Young Students and Amateurs in Architecture, Painting, &c. By GEORGE PYNE. 2s.

40 & 41. *GLASS STAINING, AND THE ART OF PAINTING ON GLASS.* From the German of Dr. GESSERT and EMANUEL OTTO FROMBERG. With an Appendix on THE ART OF ENAMELLING. 2s. 6d.

69. *MUSIC*, A Rudimentary and Practical Treatise on. With numerous Examples. By CHARLES CHILD SPENCER. 2s. 6d.

71. *PIANOFORTE*, The Art of Playing the. With numerous Exercises & Lessons from the Best Masters. By CHARLES CHILD SPENCER. 1s. 6d.

69-71. *MUSIC AND THE PIANOFORTE.* In one volume. Half bound, 5s.

181. *PAINTING POPULARLY EXPLAINED*, including Fresco, Oil, Mosaic, Water Colour, Water-Glass, Tempera, Encaustic, Miniature, Painting on Ivory, Vellum, Pottery, Enamel, Glass, &c. With Historical Sketches of the Progress of the Art by THOMAS JOHN GULLICK, assisted by JOHN TIMBS, F.S.A. Fourth Edition, revised and enlarged. 5s.‡

186. *A GRAMMAR OF COLOURING*, applied to Decorative Painting and the Arts. By GEORGE FIELD. New Edition, enlarged and adapted to the Use of the Ornamental Painter and Designer. By ELLIS A. DAVIDSON. With two new Coloured Diagrams, &c. 3s.‡

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

AGRICULTURE, GARDENING, ETC.

66. *CLAY LANDS & LOAMY SOILS.* By Prof. DONALDSON. 1s.

131. *MILLER'S, MERCHANT'S, AND FARMER'S READY* RECKONER. With approximate values of Millstones, Millwork, &c. 1s.

140. *SOILS, MANURES, AND CROPS.* (Vol. 1. OUTLINES OF MODERN FARMING.) By R. SCOTT BURN. Woodcuts. 2s.

141. *FARMING & FARMING ECONOMY,* Notes, Historical and Practical, on. (Vol. 2. OUTLINES OF MODERN FARMING.) By R. SCOTT BURN. 3s.

142. *STOCK; CATTLE, SHEEP, AND HORSES.* (Vol. 3. OUTLINES OF MODERN FARMING.) By R. SCOTT BURN. Woodcuts. 2s. 6d.

145. *DAIRY, PIGS, AND POULTRY,* Management of the. By R. SCOTT BURN. With Notes on the Diseases of Stock. (Vol. 4. OUTLINES OF MODERN FARMING.) Woodcuts. 2s.

146. *UTILIZATION OF SEWAGE, IRRIGATION, AND* RECLAMATION OF WASTE LAND. (Vol. 5. OUTLINES OF MODERN FARMING.) By R. SCOTT BURN. Woodcuts. 2s. 6d.

*** Nos. 140-1-2-5-6, in One Vol., handsomely half-bound, entitled "OUTLINES OF MODERN FARMING." By ROBERT SCOTT BURN. Price 12s.

177. *FRUIT TREES,* The Scientific and Profitable Culture of. From the French of DU BREUIL. Revised by GEO. GLENNY. 187 Woodcuts. 3s. 6d.‡

198. *SHEEP; THE HISTORY, STRUCTURE, ECONOMY, AND* DISEASES OF. By W. C. SPOONER, M.R.V.C., &c. Fourth Edition, enlarged, including Specimens of New and Improved Breeds. 3s. 6d.‡

201. *KITCHEN GARDENING MADE EASY.* Showing how to prepare and lay out the ground, the best means of cultivating every known Vegetable and Herb, &c. By GEORGE M. F. GLENNY. 1s. 6d.‡

207. *OUTLINES OF FARM MANAGEMENT, and the Organization of Farm Labour:* Treating of the General Work of the Farm; Field and Live Stock; Details of Contract Work; Specialities of Labour, &c., &c. By ROBERT SCOTT BURN. 2s. 6d.‡

208. *OUTLINES OF LANDED ESTATES MANAGEMENT:* Treating of the Varieties of Lands, Methods of Farming, Farm Buildings, Irrigation, Drainage, &c. By R. SCOTT BURN. 2s. 6d.‡

*** *Nos. 207 & 208 in One Vol., handsomely half-bound, entitled* "OUTLINES OF LANDED ESTATES AND FARM MANAGEMENT." By R. SCOTT BURN. *Price* 6s.

209. *THE TREE PLANTER AND PLANT PROPAGATOR.* A Practical Manual on the Propagation of Forest Trees, Fruit Trees, Flowering Shrubs, Flowering Plants, &c. By SAMUEL WOOD. 2s.‡

210. *THE TREE PRUNER.* A Practical Manual on the Pruning of Fruit Trees, including also their Training and Renovation; also the Pruning of Shrubs, Climbers, and Flowering Plants. By SAMUEL WOOD. 2s.‡

*** *Nos. 209 & 210 in One Vol., handsomely half-bound, entitled* "THE TREE PLANTER, PROPAGATOR AND PRUNER." By SAMUEL WOOD. *Price* 5s.

218. *THE HAY AND STRAW MEASURER:* Being New Tables for the Use of Auctioneers, Valuers, Farmers, Hay and Straw Dealers, &c., forming a complete Calculator and Ready-Reckoner, especially adapted to persons connected with Agriculture. Fourth Edition. By JOHN STEELE. 2s.

222. *SUBURBAN FARMING.* The Laying-out and Cultivation of Farms, adapted to the Produce of Milk, Butter, and Cheese, Eggs, Poultry, and Pigs. By Prof. JOHN DONALDSON and R. SCOTT BURN. 3s. 6d.‡

231. *THE ART OF GRAFTING AND BUDDING.* By CHARLES BALTET. With Illustrations. 2s. 6d.‡ [*Just published.*

232. *COTTAGE GARDENING;* or, Flowers, Fruits, and Vegetables for Small Gardens. By E. HOBDAY. 1s. 6d. [*Just published.*

233. *GARDEN RECEIPTS.* Edited by CHARLES W. QUIN. 1s. 6d. [*Just published.*

234. *THE KITCHEN AND MARKET GARDEN.* By Contributors to "The Garden." Compiled by C. W. SHAW, Editor of "Gardening Illustrated." 430 pp. 3s.‡ [*Just published.*

LAND DRAINAGE, in Theory and Practice. By PROFESSOR SCOTT. Illustrated. [*In the press.*

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

ARITHMETIC, GEOMETRY, MATHEMATICS, ETC.

32. *MATHEMATICAL INSTRUMENTS*, a Treatise on; in which their Construction and the Methods of Testing, Adjusting, and Using them are concisely Explained. By J. F. HEATHER, M.A., of the Royal Military Academy, Woolwich. Original Edition, in 1 vol., Illustrated. 1s. 6d.

*** *In ordering the above, be careful to say, "Original Edition" (No. 32), to distinguish it from the Enlarged Edition in 3 vols. (Nos. 168-9-70.)*

60. *LAND AND ENGINEERING SURVEYING*, a Treatise on; with all the Modern Improvements. Arranged for the Use of Schools and Private Students; also for Practical Land Surveyors and Engineers. By T. BAKER, C.E. New Edition, revised by EDWARD NUGENT, C.E. Illustrated with Plates and Diagrams. 2s.‡

61*. *READY RECKONER FOR THE ADMEASUREMENT OF* LAND. By ABRAHAM ARMAN, Schoolmaster, Thurleigh, Beds. To which is added a Table, showing the Price of Work, from 2s. 6d. to £1 per acre, and Tables for the Valuation of Land, from 1s. to £1,000 per acre, and from one pole to two thousand acres in extent, &c., &c. 1s. 6d.

76. *DESCRIPTIVE GEOMETRY*, an Elementary Treatise on; with a Theory of Shadows and of Perspective, extracted from the French of G. MONGE. To which is added, a description of the Principles and Practice of Isometrical Projection; the whole being intended as an introduction to the Application of Descriptive Geometry to various branches of the Arts. By J. F. HEATHER, M.A. Illustrated with 14 Plates. 2s.

178. *PRACTICAL PLANE GEOMETRY:* giving the Simplest Modes of Constructing Figures contained in one Plane and Geometrical Construction of the Ground. By J. F. HEATHER, M.A. With 215 Woodcuts. 2s.

179. *PROJECTION:* Orthographic, Topographic, and Perspective: giving the various Modes of Delineating Solid Forms by Constructions on a Single Plane Surface. By J. F. HEATHER, M.A. [*In preparation.*

*** *The above three volumes will form a* COMPLETE ELEMENTARY COURSE OF MATHEMATICAL DRAWING.

83. *COMMERCIAL BOOK-KEEPING.* With Commercial Phrases and Forms in English, French, Italian, and German. By JAMES HADDON, M.A., Arithmetical Master of King's College School, London. 1s. 6d.

84. *ARITHMETIC*, a Rudimentary Treatise on: with full Explanations of its Theoretical Principles, and numerous Examples for Practice. For the Use of Schools and for Self-Instruction. By J. R. YOUNG, late Professor of Mathematics in Belfast College. New Edition, with Index. 1s. 6d.

84*. A KEY to the above, containing Solutions in full to the Exercises, together with Comments, Explanations, and Improved Processes, for the Use of Teachers and Unassisted Learners. By J. R. YOUNG. 1s. 6d.

85. *EQUATIONAL ARITHMETIC*, applied to Questions of Interest,
85*. Annuities, Life Assurance, and General Commerce; with various Tables by which all Calculations may be greatly facilitated. By W. HIPSLEY. 2s.

86. *ALGEBRA*, the Elements of. By JAMES HADDON, M.A., Second Mathematical Master of King's College School. With Appendix, containing miscellaneous Investigations, and a Collection of Problems in various parts of Algebra. 2s.

86*. A KEY AND COMPANION to the above Book, forming an extensive repository of Solved Examples and Problems in Illustration of the various Expedients necessary in Algebraical Operations. Especially adapted for Self-Instruction. By J. R. YOUNG. 1s. 6d.

88. *EUCLID*, THE ELEMENTS OF: with many additional Propositions
89. and Explanatory Notes: to which is prefixed, an Introductory Essay on Logic. By HENRY LAW, C.E. 2s. 6d.‡

*** *Sold also separately, viz.:—*

88. EUCLID, The First Three Books. By HENRY LAW, C.E. 1s. 6d.
89. EUCLID, Books 4, 5, 6, 11, 12. By HENRY LAW, C.E. 1s. 6d.

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

Arithmetic, Geometry, Mathematics, etc., *continued.*

90. *ANALYTICAL GEOMETRY AND CONIC SECTIONS,* a Rudimentary Treatise on. By JAMES HANN, late Mathematical Master of King's College School, London. A New Edition, re-written and enlarged by J. R. YOUNG, formerly Professor of Mathematics at Belfast College. 2s.‡

91. *PLANE TRIGONOMETRY,* the Elements of. By JAMES HANN, formerly Mathematical Master of King's College, London. 1s. 6d.

92. *SPHERICAL TRIGONOMETRY,* the Elements of. By JAMES HANN. Revised by CHARLES H. DOWLING, C.E. 1s.

*** Or with "The Elements of Plane Trigonometry," in One Volume, 2s. 6d.*

93. *MENSURATION AND MEASURING,* for Students and Practical Use. With the Mensuration and Levelling of Land for the Purposes of Modern Engineering. By T. BAKER, C.E. New Edition, with Corrections and Additions by E. NUGENT, C.E. Illustrated 1s. 6d.

102. *INTEGRAL CALCULUS,* Rudimentary Treatise on the. By HOMERSHAM COX, B.A. Illustrated. 1s.

103. *INTEGRAL CALCULUS,* Examples on the. By JAMES HANN, late of King's College, London. Illustrated. 1s.

101. *DIFFERENTIAL CALCULUS,* Elements of the. By W. S. B. WOOLHOUSE, F.R.A.S., &c. 1s. 6d.

105. *MNEMONICAL LESSONS.*—GEOMETRY, ALGEBRA, AND TRIGONOMETRY, in Easy Mnemonical Lessons. By the Rev. THOMAS PENYNGTON KIRKMAN, M.A. 1s. 6d.

136. *ARITHMETIC,* Rudimentary, for the Use of Schools and Self-Instruction. By JAMES HADDON, M.A. Revised by ABRAHAM ARMAN. 1s. 6d.

137. A KEY TO HADDON'S RUDIMENTARY ARITHMETIC. By A. ARMAN. 1s. 6d.

168. *DRAWING AND MEASURING INSTRUMENTS.* Including—I. Instruments employed in Geometrical and Mechanical Drawing, and in the Construction, Copying, and Measurement of Maps and Plans. II. Instruments used for the purposes of Accurate Measurement, and for Arithmetical Computations. By J. F. HEATHER, M.A., late of the Royal Military Academy, Woolwich, Author of "Descriptive Geometry," &c., &c. Illustrated. 1s. 6d.

169. *OPTICAL INSTRUMENTS.* Including (more especially) Telescopes, Microscopes, and Apparatus for producing copies of Maps and Plans by Photography. By J. F. HEATHER, M.A. Illustrated. 1s. 6d.

170. *SURVEYING AND ASTRONOMICAL INSTRUMENTS.* Including—I. Instruments Used for Determining the Geometrical Features of a portion of Ground. II. Instruments Employed in Astronomical Observations. By J. F. HEATHER, M.A. Illustrated. 1s. 6d.

*** The above three volumes form an enlargement of the Author's original work, "Mathematical Instruments: their Construction, Adjustment, Testing, and Use," the Thirteenth Edition of which is on sale, price 1s. 6d. (See No. 32 in the Series.)*

168., 169., 170. *MATHEMATICAL INSTRUMENTS.* By J. F. HEATHER, M.A. Enlarged Edition, for the most part entirely re-written. The 3 Parts as above, in One thick Volume. With numerous Illustrations. 4s. 6d.‡

158. *THE SLIDE RULE, AND HOW TO USE IT;* containing full, easy, and simple Instructions to perform all Business Calculations with unexampled rapidity and accuracy. By CHARLES HOARE, C.E. With a Slide Rule in tuck of cover. 2s. 6d.‡

185. *THE COMPLETE MEASURER;* setting forth the Measurement of Boards, Glass, &c., &c.; Unequal-sided, Square-sided, Octagonal-sided, Round Timber and Stone, and Standing Timber. With a Table showing the solidity of hewn or eight-sided timber, or of any octagonal-sided column. Compiled for Timber-growers. Merchants, and Surveyors, Stonemasons, Architects, and others. By RICHARD HORTON. Fourth Edition, with valuable additions. 4s.; strongly bound in leather, 5s.

196. *THEORY OF COMPOUND INTEREST AND ANNUITIES;* with Tables of Logarithms for the more Difficult Computations of Interest, Discount, Annuities, &c. By FÉDOR THOMAN. 4s.‡

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

Arithmetic, Geometry, Mathematics, etc., *continued.*

199. *INTUITIVE CALCULATIONS;* or, Easy and Compendious Methods of Performing the various Arithmetical Operations required in Commercial and Business Transactions; together with Full Explanations of Decimals and Duodecimals, several Useful Tables, &c. By DANIEL O'GORMAN. Twenty-fifth Edition, corrected and enlarged by J. R. YOUNG, formerly Professor of Mathematics in Belfast College. 3s.‡

204. *MATHEMATICAL TABLES*, for Trigonometrical, Astronomical, and Nautical Calculations; to which is prefixed a Treatise on Logarithms. By HENRY LAW, C.E. Together with a Series of Tables for Navigation and Nautical Astronomy. By J. R. YOUNG, formerly Professor of Mathematics in Belfast College. New Edition. 3s. 6d.‡

221. *MEASURES, WEIGHTS, AND MONEYS OF ALL NATIONS*, and an Analysis of the Christian, Hebrew, and Mahometan Calendars. By W. S. B. WOOLHOUSE, F.R.A.S., F.S.S. Sixth Edition, carefully revised and enlarged. 2s.‡

227. *MATHEMATICS AS APPLIED TO THE CONSTRUCTIVE ARTS.* Illustrating the various processes of Mathematical Investigation, by means of Arithmetical and Simple Algebraical Equations and Practical Examples; also the Methods of Analysing Principles and Deducing Rules and Formulæ, applicable to the Requirements of Practice. By FRANCIS CAMPIN, C.E., Author of "Materials and Construction," &c. Second Edition, revised and enlarged by the Author. 3s.‡ [*Just published.*

MISCELLANEOUS VOLUMES.

36. *A DICTIONARY OF TERMS used in ARCHITECTURE, BUILDING, ENGINEERING, MINING, METALLURGY, ARCHÆOLOGY, the FINE ARTS, &c.* By JOHN WEALE. Fifth Edition. Revised by ROBERT HUNT, F.R.S., Keeper of Mining Records. Numerous Illustrations. 5s. cloth limp; 6s. cloth boards.

50. *THE LAW OF CONTRACTS FOR WORKS AND SERVICES.* By DAVID GIBBONS. Third Edition, enlarged. 3s.‡

112. *MANUAL OF DOMESTIC MEDICINE.* By R. GOODING, B.A., M.D. Intended as a Family Guide in all Cases of Accident and Emergency. Third Edition. 2s.‡

112*. *MANAGEMENT OF HEALTH.* A Manual of Home and Personal Hygiene. By the Rev. JAMES BAIRD, B.A. 1s.

150. *LOGIC*, Pure and Applied. By S. H. EMMENS. 1s. 6d.

153. *SELECTIONS FROM LOCKE'S ESSAYS ON THE HUMAN UNDERSTANDING.* With Notes by S. H. EMMENS. 2s.

154. *GENERAL HINTS TO EMIGRANTS.* Containing Notices of the various Fields for Emigration. With Hints on Preparation for Emigrating, Outfits, &c., &c. With Directions and Recipes useful to the Emigrant. With a Map of the World. 2s.

157. *THE EMIGRANT'S GUIDE TO NATAL.* By ROBERT JAMES MANN, F.R.A.S., F.M.S. Second Edition, carefully corrected to the present Date. Map. 2s.

193. *HANDBOOK OF FIELD FORTIFICATION*, intended for the Guidance of Officers Preparing for Promotion, and especially adapted to the requirements of Beginners. By Major W. W. KNOLLYS, F.R.G.S., 93rd Sutherland Highlanders, &c. With 163 Woodcuts. 3s.‡

194. *THE HOUSE MANAGER:* Being a Guide to Housekeeping. Practical Cookery, Pickling and Preserving, Household Work, Dairy Management, the Table and Dessert, Cellarage of Wines, Home-brewing and Wine-making, the Boudoir and Dressing-room, Travelling, Stable Economy, Gardening Operations, &c. By AN OLD HOUSEKEEPER. 3s. 6d.‡

194, 112, & 112*. *HOUSE BOOK (The).* Comprising:—I. THE HOUSE MANAGER. By an OLD HOUSEKEEPER. II. DOMESTIC MEDICINE. By RALPH GOODING, M.D. III. MANAGEMENT OF HEALTH. By JAMES BAIRD. In One Vol., strongly half-bound. 6s.

☞ *The ‡ indicates that these vols. may be had strongly bound at 6d. extra.*

EDUCATIONAL AND CLASSICAL SERIES.

HISTORY.

1. **England, Outlines of the History of;** more especially with reference to the Origin and Progress of the English Constitution. By WILLIAM DOUGLAS HAMILTON, F.S.A., of Her Majesty's Public Record Office. 4th Edition, revised. 5s.; cloth boards, 6s.

5. **Greece, Outlines of the History of;** in connection with the Rise of the Arts and Civilization in Europe. By W. DOUGLAS HAMILTON, of University College, London, and EDWARD LEVIEN, M.A., of Balliol College, Oxford. 2s. 6d.; cloth boards, 3s. 6d.

7. **Rome, Outlines of the History of:** from the Earliest Period to the Christian Era and the Commencement of the Decline of the Empire. By EDWARD LEVIEN, of Balliol College, Oxford. Map, 2s. 6d.; cl. bds. 3s. 6d.

9. **Chronology of History, Art, Literature, and Progress,** from the Creation of the World to the Conclusion of the Franco-German War. The Continuation by W. D. HAMILTON, F.S.A. 3s.; cloth boards, 3s. 6d.

50. **Dates and Events in English History,** for the use of Candidates in Public and Private Examinations. By the Rev. E. RAND. 1s.

ENGLISH LANGUAGE AND MISCELLANEOUS.

11. **Grammar of the English Tongue,** Spoken and Written. With an Introduction to the Study of Comparative Philology. By HYDE CLARKE, D.C.L. Fourth Edition. 1s. 6d.

11*. **Philology:** Handbook of the Comparative Philology of English, Anglo-Saxon, Frisian, Flemish or Dutch, Low or Platt Dutch, High Dutch or German, Danish, Swedish, Icelandic, Latin, Italian, French, Spanish, and Portuguese Tongues. By HYDE CLARKE, D.C.L. 1s.

12. **Dictionary of the English Language,** as Spoken and Written. Containing above 100,000 Words. By HYDE CLARKE, D.C.L. 3s. 6d.; cloth boards, 4s. 6d.; complete with the GRAMMAR, cloth bds., 5s. 6d.

48. **Composition and Punctuation,** familiarly Explained for those who have neglected the Study of Grammar. By JUSTIN BRENAN. 17th Edition. 1s. 6d.

49. **Derivative Spelling-Book:** Giving the Origin of Every Word from the Greek, Latin, Saxon, German, Teutonic, Dutch, French, Spanish, and other Languages; with their present Acceptation and Pronunciation. By J. ROWBOTHAM, F.R.A.S. Improved Edition. 1s. 6d.

51. **The Art of Extempore Speaking:** Hints for the Pulpit, the Senate, and the Bar. By M. BAUTAIN, Vicar-General and Professor at the Sorbonne. Translated from the French. 7th Edition, carefully corrected. 2s. 6d.

52. **Mining and Quarrying,** with the Sciences connected therewith. First Book of, for Schools. By J. H. COLLINS, F.G.S., Lecturer to the Miners' Association of Cornwall and Devon. 1s.

53. **Places and Facts in Political and Physical Geography,** for Candidates in Examinations. By the Rev. EDGAR RAND, B.A. 1s.

54. **Analytical Chemistry,** Qualitative and Quantitative, a Course of. To which is prefixed, a Brief Treatise upon Modern Chemical Nomenclature and Notation. By WM. W. PINK and GEORGE E. WEBSTER. 2s.

THE SCHOOL MANAGERS' SERIES OF READING BOOKS,

Adapted to the Requirements of the New Code. Edited by the Rev. A. R. GRANT, Rector of Hitcham, and Honorary Canon of Ely; formerly H.M. Inspector of Schools.

INTRODUCTORY PRIMER, 3*d*.

	s.	d.		s.	d.
FIRST STANDARD	0	6	FOURTH STANDARD	1	2
SECOND "	0	10	FIFTH "	1	6
THIRD "	1	0	SIXTH "	1	6

LESSONS FROM THE BIBLE. Part I. Old Testament. 1s.

LESSONS FROM THE BIBLE. Part II. New Testament, to which is added THE GEOGRAPHY OF THE BIBLE, for very young Children. By Rev. C. THORNTON FORSTER. 1s. 2d. *** Or the Two Parts in One Volume. 2s.

FRENCH.

24. **French Grammar.** With Complete and Concise Rules on the Genders of French Nouns. By G. L. STRAUSS, Ph.D. 1s. 6d.

25. **French-English Dictionary.** Comprising a large number of New Terms used in Engineering, Mining, &c. By ALFRED ELWES. 1s. 6d.

26. **English-French Dictionary.** By ALFRED ELWES. 2s.

25,26. **French Dictionary** (as above). Complete, in One Vol., 3s.; cloth boards, 3s. 6d. *** Or with the GRAMMAR, cloth boards, 4s. 6d.

47. **French and English Phrase Book:** containing Introductory Lessons, with Translations, several Vocabularies of Words, a Collection of suitable Phrases, and Easy Familiar Dialogues. 1s. 6d.

GERMAN.

39. **German Grammar.** Adapted for English Students, from Heyse's Theoretical and Practical Grammar, by Dr. G. L. STRAUSS. 1s.

40. **German Reader:** A Series of Extracts, carefully culled from the most approved Authors of Germany; with Notes, Philological and Explanatory. By G. L. STRAUSS, Ph.D. 1s.

41-43. **German Triglot Dictionary.** By NICHOLAS ESTERHAZY S. A. HAMILTON. In Three Parts. Part I. German-French-English. Part II. English-German-French. Part III. French-German-English. 3s., or cloth boards, 4s.

41-43 & 39. **German Triglot Dictionary** (as above), together with German Grammar (No. 39), in One Volume, cloth boards, 5s.

ITALIAN.

27. **Italian Grammar,** arranged in Twenty Lessons, with a Course of Exercises. By ALFRED ELWES. 1s. 6d.

28. **Italian Triglot Dictionary,** wherein the Genders of all the Italian and French Nouns are carefully noted down. By ALFRED ELWES. Vol. 1. Italian-English-French. 2s. 6d.

30. **Italian Triglot Dictionary.** By A. ELWES. Vol. 2. English-French-Italian. 2s. 6d.

32. **Italian Triglot Dictionary.** By ALFRED ELWES. Vol. 3. French-Italian-English. 2s. 6d.

28,30, 32. **Italian Triglot Dictionary** (as above). In One Vol., 7s. 6d. Cloth boards.

SPANISH AND PORTUGUESE.

34. **Spanish Grammar,** in a Simple and Practical Form. With a Course of Exercises. By ALFRED ELWES. 1s. 6d.

35. **Spanish-English and English-Spanish Dictionary.** Including a large number of Technical Terms used in Mining, Engineering, &c., with the proper Accents and the Gender of every Noun. By ALFRED ELWES. 4s.; cloth boards, 5s. *** Or with the GRAMMAR, cloth boards, 6s.

55. **Portuguese Grammar,** in a Simple and Practical Form. With a Course of Exercises. By ALFRED ELWES. 1s. 6d.

56. **Portuguese-English and English-Portuguese Dictionary,** with the Genders of each Noun. By ALFRED ELWES. [*In the press.*

HEBREW.

46*. **Hebrew Grammar.** By Dr. BRESSLAU. 1s. 6d.

44. **Hebrew and English Dictionary,** Biblical and Rabbinical; containing the Hebrew and Chaldee Roots of the Old Testament Post-Rabbinical Writings. By Dr. BRESSLAU. 6s.

46. **English and Hebrew Dictionary.** By Dr. BRESSLAU. 3s.

44,46. 46*. **Hebrew Dictionary** (as above), in Two Vols., complete, with *the* GRAMMAR, cloth boards, 12s.

LATIN.

19. **Latin Grammar.** Containing the Inflections and Elementary Principles of Translation and Construction. By the Rev. THOMAS GOODWIN, M.A., Head Master of the Greenwich Proprietary School. 1s.

20. **Latin-English Dictionary.** By the Rev. THOMAS GOODWIN, M.A. 2s.

22. **English-Latin Dictionary;** together with an Appendix of French and Italian Words which have their origin from the Latin. By the Rev. THOMAS GOODWIN, M.A. 1s. 6d.

20,22. **Latin Dictionary** (as above). Complete in One Vol., 3s. 6d.; cloth boards, 4s. 6d. *** Or with the GRAMMAR, cloth boards, 5s. 6d.

LATIN CLASSICS. With Explanatory Notes in English.

1. **Latin Delectus.** Containing Extracts from Classical Authors, with Genealogical Vocabularies and Explanatory Notes, by H. YOUNG. 1s. 6d.

2. **Cæsaris** Commentarii de Bello Gallico. Notes, and a Geographica Register for the Use of Schools, by H. YOUNG. 2s.

3. **Cornelius Nepos.** With Notes. By H. YOUNG. 1s.

4. **Virgilii** Maronis Bucolica et Georgica. With Notes on the Bucolics by W. RUSHTON, M.A., and on the Georgics by H. YOUNG. 1s. 6d.

5. **Virgilii** Maronis Æneis. With Notes, Critical and Explanatory, by H. YOUNG. New Edition, revised and improved. With copious Additional Notes by Rev. T. H. L. LEARY, D.C.L., formerly Scholar of Brasenose College, Oxford. 3s.

5* ——— Part 1. Books i.—vi., 1s. 6d.

5** ——— Part 2. Books vii.—xii., 2s.

6. **Horace;** Odes, Epode, and Carmen Sæculare. Notes by H. YOUNG. 1s. 6d.

7. **Horace;** Satires, Epistles, and Ars Poetica. Notes by W. BROWNRIGG SMITH, M.A., F.R.G.S. 1s. 6d.

8. **Sallustii** Crispi Catalina et Bellum Jugurthinum. Notes, Critical and Explanatory, by W. M. DONNE, B.A., Trin. Coll., Cam. 1s. 6d.

9. **Terentii** Andria et Heautontimorumenos. With Notes, Critical and Explanatory, by the Rev. JAMES DAVIES, M.A. 1s. 6d.

10. **Terentii** Adelphi, Hecyra, Phormio. Edited, with Notes, Critical and Explanatory, by the Rev. JAMES DAVIES, M.A. 2s.

11. **Terentii** Eunuchus, Comœdia. Notes, by Rev. J. DAVIES, M.A. 1s. 6d.

12. **Ciceronis** Oratio pro Sexto Roscio Amerino. Edited, with an Introduction, Analysis, and Notes, Explanatory and Critical, by the Rev. JAMES DAVIES, M.A. 1s.

13. **Ciceronis** Orationes in Catilinam, Verrem, et pro Archia. With Introduction, Analysis, and Notes, Explanatory and Critical, by Rev. T. H. L. LEARY, D.C.L. formerly Scholar of Brasenose College, Oxford. 1s. 6d.

14. **Ciceronis** Cato Major, Lælius, Brutus, sive de Senectute, de Amicitia, de Claris Oratoribus Dialogi. With Notes by W. BROWNRIGG SMITH, M.A., F.R.G.S. 2s.

16. **Livy:** History of Rome. Notes by H. YOUNG and W. B. SMITH, M.A. Part 1. Books i., ii., 1s. 6d.

16*. ——— Part 2. Books iii., iv., v., 1s. 6d.

17. ——— Part 3. Books xxi., xxii., 1s. 6d.

19. **Latin Verse Selections,** from Catullus, Tibullus, Propertius, and Ovid. Notes by W. B. DONNE, M.A., Trinity College, Cambridge. 2s.

20. **Latin Prose Selections,** from Varro, Columella, Vitruvius, Seneca, Quintilian, Florus, Velleius Paterculus, Valerius Maximus Suetonius, Apuleius, &c. Notes by W. B. DONNE, M.A. 2s.

21. **Juvenalis** Satiræ. With Prolegomena and Notes by T. H. S. ESCOTT, B.A., Lecturer on Logic at King's College, London. 2s.

GREEK.

14. **Greek Grammar**, in accordance with the Principles and Philological Researches of the most eminent Scholars of our own day. By HANS CLAUDE HAMILTON. 1s. 6d.

15,17. **Greek Lexicon.** Containing all the Words in General Use, with their Significations, Inflections, and Doubtful Quantities. By HENRY R. HAMILTON. Vol. 1. Greek-English, 2s. 6d.; Vol. 2. English-Greek, 2s. Or the Two Vols. in One, 4s. 6d.: cloth boards, 5s.

14,15. 17. **Greek Lexicon** (as above). Complete, with the GRAMMAR, in One Vol., cloth boards, 6s.

GREEK CLASSICS. With Explanatory Notes in English.

1. **Greek Delectus.** Containing Extracts from Classical Authors, with Genealogical Vocabularies and Explanatory Notes, by H. YOUNG. New Edition, with an improved and enlarged Supplementary Vocabulary, by JOHN HUTCHISON, M.A., of the High School, Glasgow. 1s. 6d.

2, 3. **Xenophon's Anabasis**; or, The Retreat of the Ten Thousand. Notes and a Geographical Register, by H. YOUNG. Part 1. Books i. to iii., 1s. Part 2. Books iv. to vii., 1s.

4. **Lucian's Select Dialogues.** The Text carefully revised, with Grammatical and Explanatory Notes, by H. YOUNG. 1s. 6d.

5-12. **Homer, The Works of.** According to the Text of BAEUMLEIN. With Notes, Critical and Explanatory, drawn from the best and latest Authorities, with Preliminary Observations and Appendices, by T. H. L. LEARY, M.A., D.C.L.

THE ILIAD:	Part 1. Books i. to vi., 1s. 6d.	Part 3. Books xiii. to xviii., 1s. 6d.
	Part 2. Books vii. to xii., 1s. 6d.	Part 4. Books xix. to xxiv., 1s. 6d.
THE ODYSSEY.	Part 1. Books i. to vi., 1s. 6d	Part 3. Books xiii. to xviii., 1s. 6d.
	Part 2. Books vii. to xii., 1s. 6d.	Part 4. Books xix. to xxiv., and Hymns, 2s.

13. **Plato's Dialogues:** The Apology of Socrates, the Crito, and the Phædo. From the Text of C. F. HERMANN. Edited with Notes, Critical and Explanatory, by the Rev. JAMES DAVIES, M.A. 2s.

14-17. **Herodotus, The History of,** chiefly after the Text of GAISFORD. With Preliminary Observations and Appendices, and Notes, Critical and Explanatory, by T. H. L. LEARY, M.A., D.C.L.
Part 1. Books i., ii. (The Clio and Euterpe), 2s.
Part 2. Books iii., iv. (The Thalia and Melpomene), 2s.
Part 3. Books v.-vii. (The Terpsichore, Erato, and Polymnia), 2s.
Part 4. Books viii., ix. (The Urania and Calliope) and Index, 1s. 6d.

18. **Sophocles:** Œdipus Tyrannus. Notes by H. YOUNG. 1s.

20. **Sophocles:** Antigone. From the Text of DINDORF. Notes, Critical and Explanatory, by the Rev. JOHN MILNER, B.A. 2s.

23. **Euripides:** Hecuba and Medea. Chiefly from the Text of DINDORF. With Notes, Critical and Explanatory, by W. BROWNRIGG SMITH, M.A., F.R.G.S. 1s. 6d.

26. **Euripides:** Alcestis. Chiefly from the Text of DINDORF. With Notes, Critical and Explanatory, by JOHN MILNER, B.A. 1s. 6d.

30. **Æschylus:** Prometheus Vinctus: The Prometheus Bound. From the Text of DINDORF. Edited, with English Notes, Critical and Explanatory, by the Rev. JAMES DAVIES, M.A. 1s.

32. **Æschylus:** Septem Contra Thebes: The Seven against Thebes. From the Text of DINDORF. Edited, with English Notes, Critical and Explanatory, by the Rev. JAMES DAVIES, M.A. 1s.

40. **Aristophanes:** Acharnians. Chiefly from the Text of C. H. WEISE. With Notes, by C. S. T. TOWNSHEND, M.A. 1s. 6d.

41. **Thucydides:** History of the Peloponnesian War. Notes by H. YOUNG. Book 1. 1s.

42. **Xenophon's Panegyric on Agesilaus.** Notes and Introduction by LL. F. W. JEWITT. 1s. 6d.

43. **Demosthenes.** The Oration on the Crown and the Philippics. *With English* Notes. By Rev. T. H. L. LEARY, D.C.L., formerly Scholar of *Brasenose* College, Oxford. 1s. 6d.

LONDON, *October*, 1882.

A Catalogue of Books

INCLUDING MANY NEW AND STANDARD WORKS IN

ENGINEERING, ARCHITECTURE, AGRICULTURE, MATHEMATICS, MECHANICS, SCIENCE, ETC.

PUBLISHED BY

CROSBY LOCKWOOD & CO.,

7, STATIONERS'-HALL COURT, LUDGATE HILL, E.C.

ENGINEERING, SURVEYING, ETC.

Humber's New Work on Water-Supply.

A COMPREHENSIVE TREATISE on the WATER-SUPPLY of CITIES and TOWNS. By WILLIAM HUMBER, A.-M. Inst. C.E., and M. Inst. M.E. Illustrated with 50 Double Plates, 1 Single Plate, Coloured Frontispiece, and upwards of 250 Woodcuts, and containing 400 pages of Text. Imp. 4to, 6*l.* 6*s.* elegantly and substantially half-bound in morocco.

List of Contents:—

I. Historical Sketch of some of the means that have been adopted for the Supply of Water to Cities and Towns.—II. Water and the Foreign Matter usually associated with it.—III. Rainfall and Evaporation.—IV. Springs and the water-bearing formations of various districts.—V. Measurement and Estimation of the Flow of Water.—VI. On the Selection of the Source of Supply.—VII. Wells.—VIII. Reservoirs.—IX. The Purification of Water.—X. Pumps.—XI. Pumping Machinery.—XII. Conduits.—XIII. Distribution of Water.—XIV. Meters, Service Pipes, and House Fittings.—XV. The Law and Economy of Water Works.—XVI. Constant and Intermittent Supply.—XVII. Description of Plates.—Appendices, giving Tables of Rates of Supply, Velocities, &c. &c., together with Specifications of several Works illustrated, among which will be found:—Aberdeen, Bideford, Canterbury, Dundee, Halifax, Lambeth, Rotherham, Dublin, and others.

"The most systematic and valuable work upon water supply hitherto produced in English, or in any other language . . . . Mr. Humber's work is characterised almost throughout by an exhaustiveness much more distinctive of French and German than of English technical treatises."—*Engineer.*

Humber's Great Work on Bridge Construction.

A COMPLETE and PRACTICAL TREATISE on CAST and WROUGHT-IRON BRIDGE CONSTRUCTION, including Iron Foundations. In Three Parts—Theoretical, Practical, and Descriptive. By WILLIAM HUMBER, A.-M. Inst. C.E., and M. Inst. M.E. Third Edition, with 115 Double Plates. In 2 vols. imp. 4to, 6*l.* 16*s.* 6*d.* half-bound in morocco.

"A book—and particularly a large and costly treatise like Mr. Humber's—which has reached its third edition may certainly be said to have established its own reputation."—*Engineering.*

Humber's Modern Engineering.

A RECORD of the PROGRESS of MODERN ENGINEERING. First Series. Comprising Civil, Mechanical, Marine, Hydraulic, Railway, Bridge, and other Engineering Works, &c. By WILLIAM HUMBER, A.-M. Inst. C.E., &c. Imp. 4to, with 36 Double Plates, drawn to a large scale, and Portrait of John Hawkshaw, C.E., F.R.S., &c., and descriptive Letter-press, Specifications, &c. 3*l.* 3*s.* half morocco.

List of the Plates and Diagrams.

Victoria Station and Roof, L. B. & S. C. R. (8 plates); Southport Pier (2 plates); Victoria Station and Roof, L. C. & D. and G. W. R. (6 plates); Roof of Cremorne Music Hall; Bridge over G. N. Railway; Roof of Station, Dutch Rhenish Rail (2 plates); Bridge over the Thames, West London Extension Railway (5 plates); Armour Plates; Suspension Bridge, Thames (4 plates): The Allen Engine; Suspension Bridge, Avon (3 plates); Underground Railway (3 plates).

"Handsomely lithographed and printed. It will find favour with many who desire to preserve in a permanent form copies of the plans and specifications prepared for the guidance of the contractors for many important engineering works."—*Engineer.*

HUMBER'S RECORD OF MODERN ENGINEERING. Second Series. Imp. 4to, with 36 Double Plates, Portrait of Robert Stephenson, C.E., &c., and descriptive Letterpress, Specifications, &c. 3*l.* 3*s.* half morocco.

List of the Plates and Diagrams.

Birkenhead Docks, Low Water Basin (15 plates); Charing Cross Station Roof, C. C. Railway (3 plates); Digswell Viaduct, G. N. Railway; Robbery Wood Viaduct, G. N. Railway; Iron Permanent Way; Clydach Viaduct, Merthyr, Tredegar, and Abergavenny Railway; Ebbw Viaduct, Merthyr, Tredegar, and Abergavenny Railway; College Wood Viaduct, Cornwall Railway; Dublin Winter Palace Roof (3 plates); Bridge over the Thames, L. C. and D. Railway (6 plates); Albert Harbour, Greenock (4 plates).

HUMBER'S RECORD OF MODERN ENGINEERING. Third Series. Imp. 4to, with 40 Double Plates, Portrait of J. R. M'Clean, Esq., late Pres. Inst. C.E., and descriptive Letterpress, Specifications, &c. 3*l.* 3*s.* half morocco.

List of the Plates and Diagrams.

MAIN DRAINAGE, METROPOLIS.—*North Side.*—Map showing Interception of Sewers; Middle Level Sewer (2 plates); Outfall Sewer, Bridge over River Lea (3 plates); Outfall Sewer, Bridge over Marsh Lane, North Woolwich Railway, and Bow and Barking Railway Junction; Outfall Sewer, Bridge over Bow and Barking Railway (3 plates); Outfall Sewer, Bridge over East London Waterworks' Feeder (2 plates); Outfall Sewer, Reservoir (2 plates); Outfall Sewer, Tumbling Bay and Outlet; Outfall Sewer, Penstocks. *South Side.*—Outfall Sewer, Bermondsey Branch (2 plates); Outfall Sewer, Reservoir and Outlet (4 plates); Outfall Sewer, Filth Hoist; Sections of Sewers (North and South Sides).

THAMES EMBANKMENT.—Section of River Wall; Steamboat Pier, Westminster (2 plates); Landing Stairs between Charing Cross and Waterloo Bridges; York Gate (2 plates); Overflow and Outlet at Savoy Street Sewer (3 plates); Steamboat Pier, Waterloo Bridge (3 plates); Junction of Sewers, Plans and Sections; Gullies, Plans and Sections; Rolling Stock; Granite and Iron Forts.

HUMBER'S RECORD OF MODERN ENGINEERING. Fourth Series. Imp. 4to, with 36 Double Plates, Portrait of John Fowler, Esq., late Pres. Inst. C.E., and descriptive Letterpress, Specifications, &c. 3*l.* 3*s.* half morocco.

List of the Plates and Diagrams.

Abbey Mills Pumping Station, Main Drainage, Metropolis (4 plates); Barrow Docks (5 plates); Manquis Viaduct, Santiago and Valparaiso Railway (2 plates); Adam's Locomotive, St. Helen's Canal *Railway (2 plates)*; Cannon Street Station *Roof*, Charing Cross Railway (3 plates); *Road Bridge* over the River Moka (2 *plates*). *Telegraphic* Apparatus for Mesopotamia; Viaduct over the River Wye, Midland Railway (3 plates); St. German's Viaduct, Cornwall Railway (2 plates); Wrought-Iron Cylinder for Diving Bell; Millwall Docks (6 plates); Milroy's Patent Excavator, Metropolitan District Railway (6 plates); Harbours, Ports, and Breakwaters (3 plates).

Strains, Formulæ & Diagrams for Calculation of.

A HANDY BOOK for the CALCULATION of STRAINS in GIRDERS and SIMILAR STRUCTURES, and their STRENGTH; consisting of Formulæ and Corresponding Diagrams, with numerous Details for Practical Application, &c. By WILLIAM HUMBER, A.-M. Inst. C.E., &c. Third Edition. With nearly 100 Woodcuts and 3 Plates, Crown 8vo, 7*s*. 6*d*. cloth.

"The system of employing diagrams as a substitute for complex computations is one justly coming into great favour, and in that respect Mr. Humber's volume is fully up to the times."—*Engineering.*

Strains.

THE STRAINS ON STRUCTURES OF IRONWORK; with Practical Remarks on Iron Construction. By F. W. SHEILDS, M. Inst. C.E. Second Edition, with 5 Plates. Royal 8vo, 5*s*. cloth.

"The student cannot find a better book on this subject than Mr. Sheilds'."—*Engineer.*

Barlow on the Strength of Materials, enlarged.

A TREATISE ON THE STRENGTH OF MATERIALS, with Rules for application in Architecture, the Construction of Suspension Bridges, Railways, &c.; and an Appendix on the Power of Locomotive Engines, and the effect of Inclined Planes and Gradients. By PETER BARLOW, F.R.S. A New Edition, revised by his Sons, P. W. BARLOW, F.R.S., and W. H. BARLOW, F.R.S. The whole arranged and edited by W. HUMBER, A-M. Inst. C.E. 8vo, 400 pp., with 19 large Plates, 18*s*. cloth.

"The standard treatise upon this particular subject."—*Engineer.*

Strength of Cast Iron, &c.

A PRACTICAL ESSAY on the STRENGTH of CAST IRON and OTHER METALS. By T. TREDGOLD, C.E. 5th Edition. To which are added, Experimental Researches on the Strength, &c., of Cast Iron, by E. HODGKINSON, F.R.S. 8vo, 12*s*. cloth.

*** HODGKINSON'S RESEARCHES, separate, price 6*s*.

Hydraulics.

HYDRAULIC TABLES, CO-EFFICIENTS, and FORMULÆ for finding the Discharge of Water from Orifices, Notches, Weirs, Pipes, and Rivers. With New Formulæ, Tables, and General Information on Rain-fall, Catchment-Basins, Drainage, Sewerage, Water Supply for Towns and Mill Power. By JOHN NEVILLE, Civil Engineer, M.R.I.A. Third Edition, carefully revised, with considerable Additions. Numerous Illustrations. Cr. 8vo, 14*s*. cloth.

"Undoubtedly an exceedingly useful and elaborate compilation."—*Iron.*

"Alike valuable to students and engineers in practice."—*Mining Journal.*

River Engineering.

RIVER BARS: Notes on the Causes of their Formation, and on their Treatment by 'Induced Tidal Scour,' with a Description of the Successful Reduction by this Method of the Bar at Dublin. By I. J. MANN, Assistant Engineer to the Dublin Port and Docks Board. With Illustrations. Royal 8vo. 7*s*. 6*d*. cloth.

Hydraulics.

HYDRAULIC MANUAL. Consisting of Working Tables and Explanatory Text. Intended as a Guide in Hydraulic Calculations and Field Operations. By LOWIS D'A. JACKSON. Fourth *Edition.* Rewritten and Enlarged. Large Crown 8vo. [In the pre

Levelling.

A TREATISE on the PRINCIPLES and PRACTICE of LEVELLING; showing its Application to Purposes of Railway and Civil Engineering, in the Construction of Roads; with Mr. TELFORD'S Rules for the same. By FREDERICK W. SIMMS, F.G.S., M. Inst. C.E. Sixth Edition, very carefully revised, with the addition of Mr. LAW'S Practical Examples for Setting out Railway Curves, and Mr. TRAUTWINE'S Field Practice of Laying out Circular Curves. With 7 Plates and numerous Woodcuts. 8vo, 8*s*. 6*d*. cloth. *** TRAUTWINE on Curves, separate, 5*s*.

"The text-book on levelling in most of our engineering schools and colleges."—*Engineer.*

Practical Tunnelling.

PRACTICAL TUNNELLING: Explaining in detail the Setting out of the Works, Shaft-sinking and Heading-Driving, Ranging the Lines and Levelling under Ground, Sub-Excavating, Timbering, and the Construction of the Brickwork of Tunnels with the amount of labour required for, and the Cost of, the various portions of the work. By F. W. SIMMS, M. Inst. C.E. Third Edition, Revised and Extended. By D. KINNEAR CLARK, M.I.C.E. Imp. 8vo, with 21 Folding Plates and numerous Wood Engravings, 30*s*. cloth.

"It has been regarded from the first as a text-book of the subject. . . . Mr. Clark has added immensely to the value of the book."—*Engineer.*

Steam.

STEAM AND THE STEAM ENGINE, Stationary and Portable. Being an Extension of Sewell's Treatise on Steam. By D. KINNEAR CLARK, M.I.C.E. Second Edition. 12mo, 4*s*. cloth.

Civil and Hydraulic Engineering.

CIVIL ENGINEERING. By HENRY LAW, M. Inst. C.E. Including a Treatise on Hydraulic Engineering, by GEORGE R. BURNELL, M.I.C.E. Sixth Edition, Revised, with large additions on Recent Practice in Civil Engineering, by D. KINNEAR CLARK, M. Inst. C.E. 12mo, 7*s*. 6*d*., cloth boards.

Gas-Lighting.

COMMON SENSE FOR GAS-USERS: a Catechism of Gas-Lighting for Householders, Gasfitters, Millowners, Architects, Engineers, &c. By R. WILSON, C.E. 2nd Edition. Cr. 8vo, 2*s*. 6*d*.

Bridge Construction in Masonry, Timber, & Iron.

EXAMPLES OF BRIDGE AND VIADUCT CONSTRUCTION IN MASONRY, TIMBER, AND IRON; consisting of 46 Plates from the Contract Drawings or Admeasurement of select Works. By W. DAVIS HASKOLL, C.E. Second Edition, with the addition of 554 Estimates, and the Practice of Setting out Works, with 6 pages of Diagrams. Imp. 4to, 2*l*. 12*s*. 6*d*. half-morocco.

"A work of the present nature by a man of Mr. Haskoll's experience, must prove invaluable. The tables of estimates considerably enhance its value."—*Engineering.*

Earthwork.

EARTHWORK TABLES, showing the Contents in Cubic Yards of Embankments, Cuttings, &c., of Heights or Depths up to an average of 80 feet. By JOSEPH BROADBENT, C.E., and FRANCIS CAMPIN, C.E. Cr. 8vo, oblong, 5*s*. cloth.

Tramways and their Working.

TRAMWAYS: their CONSTRUCTION and WORKING. With Special Reference to the Tramways of the United Kingdom. By D. KINNEAR CLARK, M.I.C.E. SUPPLEMENTARY VOLUME; recording the Progress recently made in the Design and Construction of Tramways, and in the Means of Locomotion by Mechanical Power. With Wood Engravings. 8vo, 12*s.* cloth.

Tramways and their Working.

TRAMWAYS: their CONSTRUCTION and WORKING. By D. KINNEAR CLARK, M. Inst. C. E. With Wood Engravings, and thirteen folding Plates. THE COMPLETE WORK, in 2 vols., Large Crown 8vo, 30*s.* cloth.

"All interested in tramways must refer to it, as all railway engineers have turned to the author's work 'Railway Machinery.'"—*The Engineer.*

Pioneer Engineering.

PIONEER ENGINEERING. A Treatise on the Engineering Operations connected with the Settlement of Waste Lands in New Countries. By EDWARD DOBSON, A.I.C.E. With Plates and Wood Engravings. Revised Edition. 12mo, 5*s.* cloth.

"A workmanlike production, and one without possession of which no man should start to encounter the duties of a pioneer engineer."—*Athenæum.*

Steam Engine.

TEXT-BOOK ON THE STEAM ENGINE. By T. M. GOODEVE, M.A., Barrister-at-Law, Author of "The Principles of Mechanics," "The Elements of Mechanism," &c. Fourth Edition. With numerous Illustrations. Crown 8vo, 6*s.* cloth.

"Mr. Goodeve's text-book is a work of which every young engineer should possess himself."—*Mining Journal.*

Steam.

THE SAFE USE OF STEAM: containing Rules for Unprofessional Steam Users. By an ENGINEER. 4th Edition. Sewed, 6*d.*

"If steam-users would but learn this little book by heart, boiler explosions would become sensations by their rarity."—*English Mechanic.*

Mechanical Engineering.

DETAILS OF MACHINERY: Comprising Instructions for the Execution of various Works in Iron, in the Fitting-Shop, Foundry, and Boiler-Yard. Arranged expressly for the use of Draughtsmen, Students, and Foremen Engineers. By FRANCIS CAMPIN, C.E. 12mo. 3*s.* 6*d.* cloth. [*Just published.*

Mechanical Engineering.

MECHANICAL ENGINEERING: Comprising Metallurgy, Moulding, Casting, Forging, Tools, Workshop Machinery, Manufacture of the Steam Engine, &c. By F. CAMPIN, C.E. 3*s.* cloth.

Works of Construction.

MATERIALS AND CONSTRUCTION: a Theoretical and Practical Treatise on the Strains, Designing, and Erection of Works of Construction. By F. CAMPIN, C.E. 12mo. 3*s.* 6*d.* cl. brds.

Iron Bridges, Girders, Roofs, &c.

A TREATISE ON THE APPLICATION OF IRON TO THE CONSTRUCTION OF BRIDGES, GIRDERS, ROOFS, AND OTHER WORKS. By F. CAMPIN, C.E. 12mo, 3*s.*

Boiler Construction.

THE MECHANICAL ENGINEER'S OFFICE BOOK: Boiler Construction. By NELSON FOLEY, Cardiff, late Assistant Manager Palmer's Engine Works, Jarrow. With 29 full-page Lithographic Diagrams. Folio 21*s.* half-bound.

Oblique Arches.

A PRACTICAL TREATISE ON THE CONSTRUCTION of OBLIQUE ARCHES. By JOHN HART. 3rd Ed. Imp. 8vo, 8*s.* cloth.

Oblique Bridges.

A PRACTICAL and THEORETICAL ESSAY on OBLIQUE BRIDGES, with 13 large Plates. By the late GEO. WATSON BUCK, M.I.C.E. Third Edition, revised by his Son, J. H. WATSON BUCK, M.I.C.E.; and with the addition of Description to Diagrams for Facilitating the Construction of Oblique Bridges, by W. H. BARLOW, M.I.C.E. Royal 8vo, 12*s.* cloth.

"The standard text book for all engineers regarding skew arches."—*Engineer.*

Gas and Gasworks.

THE CONSTRUCTION OF GASWORKS AND THE MANUFACTURE AND DISTRIBUTION OF COAL-GAS. Originally written by S. HUGHES, C.E. Sixth Edition. Re-written and enlarged, by W. RICHARDS, C.E. 12mo, 5*s.* cloth.

Waterworks for Cities and Towns.

WATERWORKS for the SUPPLY of CITIES and TOWNS, with a Description of the Principal Geological Formations of England as influencing Supplies of Water. By S. HUGHES. 4*s.* 6*d.* cloth.

Locomotive-Engine Driving.

LOCOMOTIVE-ENGINE DRIVING; a Practical Manual for Engineers in charge of Locomotive Engines. By MICHAEL REYNOLDS, M.S.E. Fifth Edition. Comprising A KEY TO THE LOCOMOTIVE ENGINE. With Illustrations. Cr. 8vo, 4*s.* 6*d.* cl.

"Mr. Reynolds has supplied a want, and has supplied it well."—*Engineer.*

The Engineer, Fireman, and Engine-Boy.

THE MODEL LOCOMOTIVE ENGINEER, FIREMAN, AND ENGINE-BOY. By M. REYNOLDS. Crown 8vo, 4*s.* 6*d.*

Stationary Engine Driving.

STATIONARY ENGINE DRIVING. A Practical Manual for Engineers in Charge of Stationary Engines. By MICHAEL REYNOLDS. Second Edition, Revised and Enlarged. With Plates and Woodcuts. Crown 8vo, 4*s.* 6*d.* cloth. [*Just published.*

Engine-Driving Life.

ENGINE-DRIVING LIFE; or Stirring Adventures and Incidents in the Lives of Locomotive Engine-Drivers. By MICHAEL REYNOLDS. Crown 8vo, 2*s.* cloth.

Continuous Railway Brakes.

CONTINUOUS RAILWAY BRAKES. A Practical Treatise on the several Systems in Use in the United Kingdom; their Construction and Performance. With copious Illustrations and numerous Tables. By MICHAEL REYNOLDS. Large Crown 8vo, 9*s.* cloth. [*Just published.*

Construction of Iron Beams, Pillars, &c.

IRON AND HEAT; exhibiting the Principles concerned in the construction of Iron Beams, Pillars, and Bridge Girders, and the Action of Heat in the Smelting Furnace. By J. ARMOUR, C.E. 3*s.*

Fire Engineering.

FIRES, FIRE-ENGINES, AND FIRE BRIGADES. With a History of Fire-Engines, their Construction, Use, and Management; Remarks on Fire-Proof Buildings, and the Preservation of Life from Fire; Statistics of the Fire Appliances in English Towns; Foreign Fire Systems; Hints on Fire Brigades, &c., &c. By CHARLES F. T. YOUNG, C.E. With numerous Illustrations, handsomely printed, 544 pp., demy 8vo, 1*l.* 4*s.* cloth.

"We can most heartily commend this book."—*Engineering.*

"Mr. Young's book on 'Fire Engines and Fire Brigades' contains a mass of information, which has been collected from a variety of sources. The subject is so intensely interesting and useful that it demands consideration."—*Building News.*

Trigonometrical Surveying.

AN OUTLINE OF THE METHOD OF CONDUCTING A TRIGONOMETRICAL SURVEY, for the Formation of Geographical and Topographical Maps and Plans, Military Reconnaissance, Levelling, &c., with the most useful Problems in Geodesy and Practical Astronomy. By LIEUT.-GEN. FROME, R.E., late Inspector-General of Fortifications. Fourth Edition, Enlarged, and partly Re-written. By CAPTAIN CHARLES WARREN, R.E. With 19 Plates and 115 Woodcuts, royal 8vo, 16*s.* cloth.

Tables of Curves.

TABLES OF TANGENTIAL ANGLES and MULTIPLES for setting out Curves from 5 to 200 Radius. By ALEXANDER BEAZELEY, M. Inst. C.E. Second Edition. Printed on 48 Cards, and sold in a cloth box, waistcoat-pocket size, 3*s.* 6*d.*

"Each table is printed on a small card, which, being placed on the theodolite, leaves the hands free to manipulate the instrument."—*Engineer.*

"Very handy; a man may know that all his day's work must fall on two of these cards, which he puts into his own card-case, and leaves the rest behind."—[*Athenæum.*

Engineering Fieldwork.

THE PRACTICE OF ENGINEERING FIELDWORK, applied to Land and Hydraulic, Hydrographic, and Submarine Surveying and Levelling. Second Edition, revised, with considerable additions, and a Supplement on WATERWORKS, SEWERS, SEWAGE, and IRRIGATION. By W. DAVIS HASKOLL, C.E. Numerous folding Plates. In 1 Vol., demy 8vo, 1*l.* 5*s.*, cl. boards.

Large Tunnel Shafts.

THE CONSTRUCTION OF LARGE TUNNEL SHAFTS. A Practical and Theoretical Essay. By J. H. WATSON BUCK, M. Inst. C.E., Resident Engineer, London and North-Western Railway. Illustrated with Folding Plates. Royal 8vo, 12*s.* cloth.

"Many of the methods given are of extreme practical value to the mason, and the observations on the form of arch, the rules for ordering the stone, and the construction of the templates, will be found of considerable use. We commend the book to the engineering profession, and to all who have to build similar shafts."—*Building News.*

"Will be regarded by civil engineers as of the utmost value, and calculated to save much time and obviate many mistakes."—*Colliery Guardian.*

Survey Practice.

AID TO SURVEY PRACTICE: for Reference in Surveying, Levelling, Setting-out and in Route Surveys of Travellers by Land and Sea. With Tables, Illustrations, and Records. By LOWIS D'A. JACKSON, A.-M.I.C.E. Author of "Hydraulic Manual and Statistics," &c. Large crown 8vo, 12*s.* 6*d.*, cloth.

"Mr. Jackson has produced a valuable *vade-mecum* for the surveyor. We can recommend this book as containing an admirable supplement to the teaching of the accomplished surveyor."—*Athenæum.*

"A general text book was wanted, and we are able to speak with confidence of Mr. Jackson's treatise. . . . We cannot recommend to the student who knows something of the mathematical principles of the subject a better course than to fortify his practice in the field under a competent surveyor with a study of Mr. Jackson's useful manual. The field records illustrate every kind of survey, and will be found an essential aid to the student."—*Building News.*

"The author brings to his work a fortunate union of theory and practical experience which, aided by a clear and lucid style of writing, renders the book both a very useful one and very agreeable to read."—*Builder.*

Sanitary Work.

SANITARY WORK IN THE SMALLER TOWNS AND IN VILLAGES. Comprising:—1. Some of the more Common Forms of Nuisance and their Remedies; 2. Drainage; 3. Water Supply. By CHAS. SLAGG, Assoc. Inst. C.E. Crown 8vo, 3*s.* cloth.

"A very useful book, and may be safely recommended. The author has had practical experience in the works of which he treats."—*Builder.*

Locomotives.

LOCOMOTIVE ENGINES, A Rudimentary Treatise on. Comprising an Historical Sketch and Description of the Locomotive Engine. By G. D. DEMPSEY, C.E. With large additions treating of the MODERN LOCOMOTIVE, by D. KINNEAR CLARK, C.E., M.I.C.E., Author of "Tramways, their Construction and Working," &c., &c. With numerous Illustrations. 12mo. 3*s.* 6*d.* cloth boards.

"The student cannot fail to profit largely by adopting this as his preliminary text-book."—*Iron and Coal Trades Review.*

"Seems a model of what an elementary technical book should be."—*Academy.*

Fuels and their Economy.

FUEL, its Combustion and Economy; consisting of an Abridgment of "A Treatise on the Combustion of Coal and the Prevention of Smoke." By C. W. WILLIAMS, A.I.C.E. With extensive additions on Recent Practice in the Combustion and Economy of Fuel—Coal, Coke, Wood, Peat, Petroleum, &c.; by D. KINNEAR CLARK, C.E., M.I.C.E. Second Edition, revised. With numerous Illustrations. 12mo. 4*s.* cloth boards.

"Students should buy the book and read it, as one of the most complete and satisfactory treatises on the combustion and economy of fuel to be had."—*Engineer.*

Roads and Streets.

THE CONSTRUCTION OF ROADS AND STREETS. In Two Parts. I. The Art of Constructing Common Roads. By HENRY LAW, C.E. Revised and Condensed. II. Recent Practice in the Construction of Roads and Streets: including Pavements of Stone, Wood, and Asphalte. By D. KINNEAR CLARK, C.E., M.I.C.E. Second Edit., revised. 12mo, 5*s.* cloth.

"*A book which every borough surveyor and engineer must possess, and which will be of considerable* service to architects, builders, and property owners generally."—*Building News.*

Sewing Machine (The).

SEWING MACHINERY; being a Practical Manual of the Sewing Machine, comprising its History and Details of its Construction, with full Technical Directions for the Adjusting of Sewing Machines. By J. W. URQUHART, Author of "Electro Plating: a Practical Manual;" "Electric Light: its Production and Use." With Numerous Illustrations. 12mo, *2s. 6d.* cloth.

Field-Book for Engineers.

THE ENGINEER'S, MINING SURVEYOR'S, and CONTRACTOR'S FIELD-BOOK. By W. DAVIS HASKOLL, C.E. Consisting of a Series of Tables, with Rules, Explanations of Systems, and Use of Theodolite for Traverse Surveying and Plotting the Work with minute accuracy by means of Straight Edge and Set Square only; Levelling with the Theodolite, Casting out and Reducing Levels to Datum, and Plotting Sections in the ordinary manner; Setting out Curves with the Theodolite by Tangential Angles and Multiples with Right and Left-hand Readings of the Instrument; Setting out Curves without Theodolite on the System of Tangential Angles by Sets of Tangents and Offsets; and Earthwork Tables to 80 feet deep, calculated for every 6 inches in depth. With numerous Woodcuts. 4th Edition, enlarged. Cr. 8vo. *12s.* cloth.

"The book is very handy, and the author might have added that the separate tables of sines and tangents to every minute will make it useful for many other purposes, the genuine traverse tables existing all the same."—*Athenæum.*

"Cannot fail, from its portability and utility, to be extensively patronised by the engineering profession."—*Mining Journal.*

Earthwork, Measurement and Calculation of.

A MANUAL on EARTHWORK. By ALEX. J. S. GRAHAM, C.E., Resident Engineer, Forest of Dean Central Railway. With numerous Diagrams. 18mo, *2s. 6d.* cloth.

"As a really handy book for reference, we know of no work equal to it; and the railway engineers and others employed in the measurement and calculation of earthwork will find a great amount of practical information very admirably arranged, and available for general or rough estimates, as well as for the more exact calculations required in the engineers' contractor's offices."—*Artizan.*

Drawing for Engineers, &c.

THE WORKMAN'S MANUAL OF ENGINEERING DRAWING. By JOHN MAXTON, Instructor in Engineering Drawing, Royal Naval College, Greenwich, formerly of R. S. N. A., South Kensington. Fourth Edition, carefully revised. With upwards of 300 Plates and Diagrams. 12mo, cloth, strongly bound, *4s.*

"A copy of it should be kept for reference in every drawing office."—*Engineering.*

"Indispensable for teachers of engineering drawing."—*Mechanics' Magazine.*

Weale's Dictionary of Terms.

A DICTIONARY of TERMS used in ARCHITECTURE, BUILDING, ENGINEERING, MINING, METALLURGY, ARCHÆOLOGY, the FINE ARTS, &c. By JOHN WEALE. Fifth Edition, revised by ROBERT HUNT, F.R.S., Keeper of Mining Records, Editor of "Ure's Dictionary of Arts." 12mo, *6s.* cl. bds.

"The best small technological dictionary in the language."—*Architect.*

"The absolute accuracy of a work of this character can only be judged of after extensive consultation, and from our examination it appears very correct and very complete."—*Mining Journal.*

MINING, METALLURGY, ETC.

Coal and Iron.

THE COAL AND IRON INDUSTRIES OF THE UNITED KINGDOM : comprising a Description of the Coal Fields, and of the Principal Seams of Coal, with returns of their Produce and its Distribution, and Analyses of Special Varieties. Also, an Account of the occurrence of Iron Ores in Veins or Seams ; Analyses of each Variety ; and a History of the Rise and Progress of Pig Iron Manufacture since the year 1740, exhibiting the economies introduced in the Blast Furnaces for its Production and Improvement. By RICHARD MEADE, Assistant Keeper of Mining Records. With Maps of the Coal Fields and Ironstone Deposits of the United Kingdom. 8vo., £1 8*s.* cloth. [*Just published.*

Metalliferous Minerals and Mining.

A TREATISE ON METALLIFEROUS MINERALS AND MINING. By D.C. DAVIES, F.G.S., author of "A Treatise on Slate and Slate Quarrying." With numerous wood engravings. Second Edition, revised. Cr. 8vo. 12*s.* 6*d.* cloth.

"Without question, the most exhaustive and the most practically useful work we have seen ; the amount of information given is enormous, and it is given concisely and intelligibly."—*Mining Journal.*

Slate and Slate Quarrying.

A TREATISE ON SLATE AND SLATE QUARRYING, Scientific, Practical, and Commercial. By D. C. DAVIES, F.G.S., Mining Engineer, &c. With numerous Illustrations and Folding Plates. Second Edition, carefully revised. 12mo, 3*s.* 6*d.* cloth boards.

"Mr. Davies has written a useful and practical hand-book on an important industry, with all the conditions and details of which he appears familiar."—*Engineering.*

Metallurgy of Iron.

A TREATISE ON THE METALLURGY OF IRON : containing Outlines of the History of Iron Manufacture, Methods of Assay, and Analyses of Iron Ores, Processes of Manufacture of Iron and Steel, &c. By H. BAUERMAN, F.G.S. Fifth Edition, Revised and greatly Enlarged. With Numerous Illustrations, 12mo. 5*s.* 6*d.*, cloth boards. [*Just published.*

Manual of Mining Tools.

MINING TOOLS. For the use of Mine Managers, Agents, Mining Students, &c. By WILLIAM MORGANS. Volume of Text. 12mo, 3*s.* With an Atlas of Plates, containing 235 Illustrations. 4to, 6*s.* Together, 9*s.* cloth boards.

Mining, Surveying and Valuing.

THE MINERAL SURVEYOR AND VALUER'S COMPLETE GUIDE, comprising a Treatise on Improved Mining Surveying, with new Traverse Tables ; and Descriptions of Improved Instruments ; also an Exposition of the Correct Principles of Laying out and Valuing Home and Foreign Iron and Coal Mineral Properties. By WILLIAM LINTERN, Mining and Civil Engineer. With four Plates of Diagrams, Plans, &c., 12mo, 4*s.* cloth.

*** *The above,* bound with THOMAN'S TABLES. (See page 20.) *Price* 7*s.* 6*d.* cloth.

Coal and Coal Mining.

COAL AND COAL MINING: a Rudimentary Treatise on. By WARINGTON W. SMYTH, M.A., F.R.S., &c., Chief Inspector of the Mines of the Crown. Fifth edition, revised and corrected. 12mo, with numerous Illustrations, 4*s*. cloth boards.

"Every portion of the volume appears to have been prepared with much care, and as an outline is given of every known coal-field in this and other countries, as well as of the two principal methods of working, the book will doubtless interest a very large number of readers."—*Mining Journal.*

Underground Pumping Machinery.

MINE DRAINAGE; being a Complete and Practical Treatise on Direct-Acting Underground Steam Pumping Machinery, with a Description of a large number of the best known Engines, their General Utility and the Special Sphere of their Action, the Mode of their Application, and their merits compared with other forms of Pumping Machinery. By STEPHEN MICHELL, Joint-Author of "The Cornish System of Mine Drainage." 8vo, 15*s*. cloth.

NAVAL ARCHITECTURE, NAVIGATION, ETC.

Pocket Book for Naval Architects & Shipbuilders.

THE NAVAL ARCHITECT'S AND SHIPBUILDER'S POCKET BOOK OF FORMULÆ, RULES, AND TABLES AND MARINE ENGINEER'S AND SURVEYOR'S HANDY BOOK OF REFERENCE. By CLEMENT MACKROW, M. Inst. N. A., Naval Draughtsman. Second Edition, revised. With numerous Diagrams. Fcap., 12*s*. 6*d*., strongly bound in leather.

"Should be used by all who are engaged in the construction or design of vessels." —*Engineer.*

"There is scarcely a subject on which a naval architect or shipbuilder can require to refresh his memory which will not be found within the covers of Mr. Mackrow's book."—*English Mechanic.*

"Mr. Mackrow has compressed an extraordinary amount of information into this useful volume."—*Athenæum.*

Grantham's Iron Ship-Building.

ON IRON SHIP-BUILDING; with Practical Examples and Details. Fifth Edition. Imp. 4to, boards, enlarged from 24 to 40 Plates (21 quite new), including the latest Examples. Together with separate Text, also considerably enlarged, 12mo, cloth limp. By JOHN GRANTHAM, M. Inst. C.E., &c. 2*l*. 2*s*. complete.

"Mr. Grantham's work is of great interest. It will, we are confident, command an extensive circulation among shipbuilders in general. By order of the Board of Admiralty, the work will form the text-book on which the examination in iron ship-building of candidates for promotion in the dockyards will be mainly based."—*Engineering.*

Pocket-Book for Marine Engineers.

A POCKET-BOOK OF USEFUL TABLES AND FORMULÆ FOR MARINE ENGINEERS. By FRANK PROCTOR, A.I.N.A. Third Edition. Royal 32mo, leather, gilt edges, 4*s*.

"A most useful companion to all marine engineers."—*United Service Gazette.*

"Scarcely anything required by a naval engineer appears to have been forgotten."—*Iron.*

Light-Houses.

EUROPEAN LIGHT-HOUSE SYSTEMS; being a Report of a Tour of Inspection made in 1873. By Major GEORGE H. ELLIOT, Corps of Engineers, U.S.A. Illustrated by 51 Engravings and 31 Woodcuts in the Text. 8vo, 21*s.* cloth.

Surveying (Land and Marine).

LAND AND MARINE SURVEYING, in Reference to the Preparation of Plans for Roads and Railways, Canals, Rivers, Towns' Water Supplies, Docks and Harbours; with Description and Use of Surveying Instruments. By W. DAVIS HASKOLL, C.E. With 14 folding Plates, and numerous Woodcuts. 8vo, 12*s.* 6*d.* cloth.

"A most useful and well arranged book for the aid of a student."—*Builder.*

"Of the utmost practical utility, and may be safely recommended to all students who aspire to become clean and expert surveyors."—*Mining Journal.*

Storms.

STORMS: their Nature, Classification, and Laws, with the Means of Predicting them by their Embodiments, the Clouds. By WILLIAM BLASIUS. Crown 8vo, 10*s.* 6*d.* cloth boards.

Rudimentary Navigation.

THE SAILOR'S SEA-BOOK: a Rudimentary Treatise on Navigation. By JAMES GREENWOOD, B.A. New and enlarged edition. By W. H. ROSSER. 12mo, 3*s.* cloth boards.

Mathematical and Nautical Tables.

MATHEMATICAL TABLES, for Trigonometrical, Astronomical and Nautical Calculations; to which is prefixed a Treatise on Logarithms. By HENRY LAW, C.E. Together with a Series of Tables for Navigation and Nautical Astronomy. By J. R. YOUNG, formerly Professor of Mathematics in Belfast College. New Edition. 12mo, 4*s.* cloth boards.

Navigation (Practical), with Tables.

PRACTICAL NAVIGATION: consisting of the Sailor's Sea-Book, by JAMES GREENWOOD and W. H. ROSSER; together with the requisite Mathematical and Nautical Tables for the Working of the Problems. By HENRY LAW, C.E., and Professor J. R. YOUNG. Illustrated with numerous Wood Engravings and Coloured Plates. 12mo, 7*s.* strongly half bound in leather.

WEALE'S RUDIMENTARY SERIES.

The following books in Naval Architecture, etc., are published in the above series:

MASTING, MAST-MAKING, AND RIGGING OF SHIPS. By ROBERT KIPPING, N.A. Fourteenth Edition. 12mo, 2*s.* 6*d.* cloth.

SAILS AND SAIL-MAKING. Tenth Edition, enlarged. By ROBERT KIPPING, N.A. Illustrated. 12mo, 3*s.* cloth boards.

NAVAL ARCHITECTURE. By JAMES PEAKE. Fourth Edition, *with Plates* and Diagrams. 12mo, 4*s.* cloth boards.

MARINE ENGINES, AND STEAM VESSELS. By ROBERT *MURRAY, C.E.* Seventh Edition. 12mo, 3*s.* 6*d.* cloth boards.

ARCHITECTURE, BUILDING, ETC.

Construction.

THE SCIENCE of BUILDING: An Elementary Treatise on the Principles of Construction. By E. WYNDHAM TARN, M.A., Architect. With 58 Wood Engravings. Second Edition, revised and enlarged, including an entirely new chapter on the Nature of Lightning, and the Means of Protecting Buildings from its Violence. Crown 8vo, *7s. 6d.* cloth.

"A very valuable book, which we strongly recommend to all students."—*Builder.*
"No architectural student should be without this hand-book."—*Architect.*

Civil and Ecclesiastical Building.

A BOOK ON BUILDING, CIVIL AND ECCLESIASTICAL, Including CHURCH RESTORATION. By Sir EDMUND BECKETT, Bart., LL.D., Q.C., F.R.A.S. Author of "Clocks and Watches and Bells," &c. 12mo, *5s.* cloth boards.

"A book which is always amusing and nearly always instructive. We are able very cordially to recommend all persons to read it for themselves."—*Times.*
"We commend the book to the thoughtful consideration of all who are interested in the building art."—*Builder.*

Villa Architecture.

A HANDY BOOK of VILLA ARCHITECTURE; being a Series of Designs for Villa Residences in various Styles. With Detailed Specifications and Estimates. By C. WICKES, Architect, Author of "The Spires and Towers of the Mediæval Churches of England," &c. 30 Plates, 4to, half morocco, gilt edges, *1l. 1s.*

*** Also an Enlarged edition of the above. 61 Plates, with Detailed Specifications, Estimates, &c. *2l. 2s.* half morocco.

Useful Text-Book for Architects.

THE ARCHITECT'S GUIDE: Being a Text-book of Useful Information for Architects, Engineers, Surveyors, Contractors, Clerks of Works, &c. By F. ROGERS. Cr. 8vo, *6s.* cloth.

"As a text-book of useful information for architects, engineers, surveyors, &c., it would be hard to find a handier or more complete little volume."—*Standard.*

The Young Architect's Book.

HINTS TO YOUNG ARCHITECTS. By G. WIGHTWICK. New Edition. By G. H. GUILLAUME. 12mo, cloth, *4s.*

"Will be found an acquisition to pupils, and a copy ought to be considered as necessary a purchase as a box of instruments."—*Architect.*

Drawing for Builders and Students.

PRACTICAL RULES ON DRAWING for the OPERATIVE BUILDER and YOUNG STUDENT in ARCHITECTURE. By GEORGE PYNE. With 14 Plates, 4to, *7s. 6d.* boards.

Boiler and Factory Chimneys.

BOILER AND FACTORY CHIMNEYS; their Draught-power and Stability, with a chapter on Lightning Conductors. By ROBERT WILSON, C.E. Crown 8vo, *3s. 6d.* cloth.

Taylor and Cresy's Rome.

THE ARCHITECTURAL ANTIQUITIES OF ROME. By the late G. L. TAYLOR, Esq., F.S.A., and EDWARD CRESY, Esq. New Edition, Edited by the Rev. ALEXANDER TAYLOR, M.A. (son of the late G. L. Taylor, Esq.) This is the only book which gives on a large scale, and with the precision of architectural measurement, the principal Monuments of Ancient Rome in plan, elevation, and detail. Large folio, with 130 Plates, half-bound, 3*l.* 3*s.*

*** Originally published in two volumes, folio, at 18*l.* 18*s.*

Vitruvius' Architecture.

THE ARCHITECTURE OF MARCUS VITRUVIUS POLLIO. Translated by JOSEPH GWILT, F.S.A., F.R.A.S. Numerous Plates. 12mo, cloth limp, 5*s.*

Ancient Architecture.

RUDIMENTARY ARCHITECTURE (ANCIENT); comprising VITRUVIUS, translated by JOSEPH GWILT, F.S.A., &c., with 23 fine plates; and GRECIAN ARCHITECTURE. By the EARL of ABERDEEN; 12mo, 6*s.*, half-bound.

*** *The only edition of VITRUVIUS procurable at a moderate price.*

Modern Architecture.

RUDIMENTARY ARCHITECTURE (MODERN); comprising THE ORDERS OF ARCHITECTURE. By W. H. LEEDS, Esq.; The STYLES of ARCHITECTURE of VARIOUS COUNTRIES. By T. TALBOT BURY; and The PRINCIPLES of DESIGN in ARCHITECTURE. By E. L. GARBETT. Numerous illustrations, 12mo, 6*s.* half-bound.

Civil Architecture.

A TREATISE on THE DECORATIVE PART of CIVIL ARCHITECTURE. By Sir WILLIAM CHAMBERS, F.R.S. With Illustrations, Notes, and an Examination of Grecian Architecture. By JOSEPH GWILT, F.S.A. Revised and edited by W. H. LEEDS. 66 Plates, 4to, 21*s.* cloth.

House Painting.

HOUSE PAINTING, GRAINING, MARBLING, AND SIGN WRITING: a Practical Manual of. With 9 Coloured Plates of Woods and Marbles, and nearly 150 Wood Engravings. By ELLIS A. DAVIDSON. Third Edition, Revised. 12mo, 6*s.* cloth.

Plumbing.

PLUMBING; a Text-book to the Practice of the Art or Craft of the Plumber. With chapters upon House-drainage, embodying the latest Improvements. By W. P. BUCHAN, Sanitary Engineer. Fourth Edition, Revised and much enlarged, with 300 illustrations, 12mo. 4*s.* cloth. [*Just published.*

Joints used in Building, Engineering, &c.

THE JOINTS MADE AND USED BY BUILDERS in the construction of various kinds of Engineering and Architectural works, with especial reference to those wrought by artificers in erecting and finishing Habitable Structures. By W. J. CHRISTY, Architect. With 160 Illustrations. 12mo, 3*s.* 6*d.* cloth boards. [*Just published.*

Handbook of Specifications.

THE HANDBOOK OF SPECIFICATIONS; or, Practical Guide to the Architect, Engineer, Surveyor, and Builder, in drawing up Specifications and Contracts for Works and Constructions. Illustrated by Precedents of Buildings actually executed by eminent Architects and Engineers. By Professor THOMAS L. DONALDSON, M.I.B.A. New Edition, in One large volume, 8vo, with upwards of 1000 pages of text, and 33 Plates, cloth, 1*l.* 11*s.* 6*d.*

"In this work forty-four specifications of executed works are given. . . . Donaldson's Handbook of Specifications must be bought by all architects."—*Builder.*

Specifications for Practical Architecture.

SPECIFICATIONS FOR PRACTICAL ARCHITECTURE: A Guide to the Architect, Engineer, Surveyor, and Builder; with an Essay on the Structure and Science of Modern Buildings. By FREDERICK ROGERS, Architect. 8vo, 15*s.* cloth.

*** A volume of specifications of a practical character being greatly required, and the old standard work of Alfred Bartholomew being out of print, the author, on the basis of that work, has produced the above.—*Extract from Preface.*

Designing, Measuring, and Valuing.

THE STUDENT'S GUIDE to the PRACTICE of MEASURING and VALUING ARTIFICERS' WORKS; containing Directions for taking Dimensions, Abstracting the same, and bringing the Quantities into Bill, with Tables of Constants, and copious Memoranda for the Valuation of Labour and Materials in the respective Trades of Bricklayer and Slater, Carpenter and Joiner, Painter and Glazier, Paperhanger, &c. With 43 Plates and Woodcuts. Originally edited by EDWARD DOBSON, Architect. New Edition, re-written, with Additions on Mensuration and Construction, and useful Tables for facilitating Calculations and Measurements. By E. WYNDHAM TARN, M.A., 8vo, 10*s.* 6*d.* cloth.

"Well fulfils the promise of its title-page. Mr. Tarn's additions and revisions have much increased the usefulness of the work."—*Engineering.*

Beaton's Pocket Estimator.

THE POCKET ESTIMATOR FOR THE BUILDING TRADES, being an easy method of estimating the various parts of a Building collectively, more especially applied to Carpenters' and Joiners' work. By A. C. BEATON. Second Edition. Waistcoat-pocket size. 1*s.* 6*d.*

Beaton's Builders' and Surveyors' Technical Guide.

THE POCKET TECHNICAL GUIDE AND MEASURER FOR BUILDERS AND SURVEYORS: containing a Complete Explanation of the Terms used in Building Construction, Memoranda for Reference, Technical Directions for Measuring Work in all the Building Trades, &c. By A. C. BEATON. 1*s.* 6*d.*

The House-Owner's Estimator.

THE HOUSE-OWNER'S ESTIMATOR; or, What will it Cost to Build, Alter, or Repair? A Price-Book for Unprofessional People, Architectural Surveyors, Builders, &c. By the late JAMES D. SIMON. Edited by F. T. W. MILLER, A.R.I.B.A. Third Edition, Revised. Crown 8vo, 3*s.* 6*d.*, cloth.

"*In two years it will repay its cost a hundred times over.*"—Field.

Cement.

PORTLAND CEMENT FOR USERS. By HENRY FAIJA, A.M. Inst. C.E., with Illustrations. Crown 8vo. 3*s*. 6*d*. cloth.

"A useful compendium of results for the builder and architect."—*Building News.*

Builder's and Contractor's Price Book.

LOCKWOOD & CO.'S BUILDER'S AND CONTRACTOR'S PRICE BOOK, containing the latest prices of all kinds of Builders' Materials and Labour, and of all Trades connected with Building, &c. Revised by F. T. W. MILLER, A.R.I.B.A. Half-bound, 4*s*.

CARPENTRY, TIMBER, ETC.

Tredgold's Carpentry, new and cheaper Edition.

THE ELEMENTARY PRINCIPLES OF CARPENTRY: a Treatise on the Pressure and Equilibrium of Timber Framing, the Resistance of Timber, and the Construction of Floors, Arches, Bridges, Roofs, Uniting Iron and Stone with Timber, &c. To which is added an Essay on the Nature and Properties of Timber, &c., with Descriptions of the Kinds of Wood used in Building; also numerous Tables of the Scantlings of Timber for different purposes, the Specific Gravities of Materials, &c. By THOMAS TREDGOLD, C.E. Edited by PETER BARLOW, F.R.S. Fifth Edition, corrected and enlarged. With 64 Plates, Portrait of the Author, and Woodcuts. 4to, published at 2*l*. 2*s*., reduced to 1*l*. 5*s*. cloth.

"Ought to be in every architect's and every builder's library, and those who do not already possess it ought to avail themselves of the new issue."—*Builder.*

"A work whose monumental excellence must commend it wherever skilful carpentry is concerned. The Author's principles are rather confirmed than impaired by time. The additional plates are of great intrinsic value."—*Building News.*

Grandy's Timber Tables.

THE TIMBER IMPORTER'S, TIMBER MERCHANT'S, & BUILDER'S STANDARD GUIDE. By R. E. GRANDY. 2nd Edition. Carefully revised and corrected. 12mo, 3*s*. 6*d*. cloth.

"Everything it pretends to be: built up gradually, it leads one from a forest to a treenail, and throws in, as a makeweight, a host of material concerning bricks, columns, cisterns, &c.—all that the class to whom it appeals requires."—*English Mechanic.*

Timber Freight Book.

THE TIMBER IMPORTERS' AND SHIPOWNERS' FREIGHT BOOK: Being a Comprehensive Series of Tables for the Use of Timber Importers, Captains of Ships, Shipbrokers, Builders, and Others. By W. RICHARDSON. Crown 8vo, 6*s*.

Tables for Packing-Case Makers.

PACKING-CASE TABLES; showing the number of Superficial Feet in Boxes or Packing-Cases, from six inches square and upwards. By W. RICHARDSON. Oblong 4to, 3*s*. 6*d*. cloth.

"Invaluable labour-saving tables."—*Ironmonger.*

Carriage Building, &c.

COACH BUILDING: A Practical Treatise, Historical and Descriptive, containing full information of the various Trades and Processes involved, with Hints on the proper keeping of Carriages, &c. 57 Illustrations. By JAMES W. BURGESS. 12mo, 3*s*. cloth.

Horton's Measurer.

THE COMPLETE MEASURER; setting forth the Measurement of Boards, Glass, &c.; Unequal-sided, Square-sided, Octagonal-sided, Round Timber and Stone, and Standing Timber. With just allowances for the bark in the respective species of trees, and proper deductions for the waste in hewing the trees, &c.; also a Table showing the solidity of hewn or eight-sided timber, or of any octagonal-sided column. By RICHARD HORTON. Fourth Edition, with considerable and valuable additions, 12mo, strongly bound in leather, 5*s.*

Horton's Underwood and Woodland Tables.

TABLES FOR PLANTING AND VALUING UNDERWOOD AND WOODLAND; also Lineal, Superficial, Cubical, and Decimal Tables, &c. By R. HORTON. 12mo, 2*s.* leather.

Nicholson's Carpenter's Guide.

THE CARPENTER'S NEW GUIDE; or, BOOK of LINES for CARPENTERS: comprising all the Elementary Principles essential for acquiring a knowledge of Carpentry. Founded on the late PETER NICHOLSON'S standard work. A new Edition, revised by ARTHUR ASHPITEL, F.S.A., together with Practical Rules on Drawing, by GEORGE PYNE. With 74 Plates, 4to, 1*l.* 1*s.* cloth.

Dowsing's Timber Merchant's Companion.

THE TIMBER MERCHANT'S AND BUILDER'S COMPANION; containing New and Copious Tables of the Reduced Weight and Measurement of Deals and Battens, of all sizes, from One to a Thousand Pieces, also the relative Price that each size bears per Lineal Foot to any given Price per Petersburgh Standard Hundred, &c., &c. Also a variety of other valuable information. By WILLIAM DOWSING, Timber Merchant. Third Edition, Revised. Crown 8vo, 3*s.* cloth.

"Everything is as concise and clear as it can possibly be made. There can be no doubt that every timber merchant and builder ought to possess it."—*Hull Advertiser.*

Practical Timber Merchant.

THE PRACTICAL TIMBER MERCHANT, being a Guide for the use of Building Contractors, Surveyors, Builders, &c., comprising useful Tables for all purposes connected with the Timber Trade, Essay on the Strength of Timber, Remarks on the Growth of Timber, &c. By W. RICHARDSON. Fcap. 8vo, 3*s.* 6*d.* cl.

Woodworking Machinery.

WOODWORKING MACHINERY; its Rise, Progress, and Construction. With Hints on the Management of Saw Mills and the Economical Conversion of Timber. Illustrated with Examples of Recent Designs by leading English, French, and American Engineers. By M. POWIS BALE, M.I.M.E. Large crown 8vo, 12*s.* 6*d.* cloth.

"Mr. Bale is evidently an expert on the subject, and he has collected so much information that his book is all-sufficient for builders and others engaged in the conversion of timber."—*Architect.*

"The most comprehensive compendium of wood-working machinery we have seen. The author is a thorough master of his subject."—*Building News.*

"It should be in the office of every wood-working factory."—*English Mechanic.*

C

MECHANICS, ETC.

Turning.

LATHE-WORK: a Practical Treatise on the Tools, Appliances, and Processes employed in the Art of Turning. By PAUL N. HASLUCK. With Illustrations drawn by the Author. Crown 8vo, 5s.

"Evidently written from personal experience, and gives a large amount of just that sort of information which beginners at the lathe require."—*Builder.*

Mechanic's Workshop Companion.

THE OPERATIVE MECHANIC'S WORKSHOP COMPANION, and THE SCIENTIFIC GENTLEMAN'S PRACTICAL ASSISTANT. By W. TEMPLETON. 13th Edit., with Mechanical Tables for Operative Smiths, Millwrights, Engineers, &c.; and an Extensive Table of Powers and Roots, 12mo, 5s. bound.

"Admirably adapted to the wants of a very large class. It has met with great success in the engineering workshop, as we can testify; and there are a great many men who, in a great measure, owe their rise in life to this little work."—*Building News.*

Engineer's and Machinist's Assistant.

THE ENGINEER'S, MILLWRIGHT'S, and MACHINIST'S PRACTICAL ASSISTANT; comprising a Collection of Useful Tables, Rules, and Data. By WM. TEMPLETON. 18mo, 2s. 6d.

Smith's Tables for Mechanics, &c.

TABLES, MEMORANDA, and CALCULATED RESULTS, FOR MECHANICS, ENGINEERS, ARCHITECTS, BUILDERS, &c. Selected and Arranged by FRANCIS SMITH. Waistcoat-pocket size, 1s. 6d., limp leather. [*Just published.*

Boiler Making.

THE BOILER-MAKER'S READY RECKONER. With Examples of Practical Geometry and Templating, for the use of Platers, Smiths, and Riveters. By JOHN COURTNEY, Edited by D. K. CLARK, M. I. C.E. 12mo, 9s. half-bd. [*Just published.*

Superficial Measurement.

THE TRADESMAN'S GUIDE TO SUPERFICIAL MEASUREMENT. Tables calculated from 1 to 200 inches in length, by 1 to 108 inches in breadth. By J. HAWKINGS. Fcp. 3s. 6d. cl.

The High-Pressure Steam Engine.

THE HIGH-PRESSURE STEAM ENGINE. By Dr. ERNST ALBAN. Translated from the German, with Notes, by Dr. POLE, F.R.S. Plates, 8vo, 16s. 6d. cloth.

Steam Boilers.

A TREATISE ON STEAM BOILERS: their Strength, Construction, and Economical Working. By R. WILSON, C.E. Fifth Edition. 12mo, 6s. cloth.

"The best work on boilers which has come under our notice."—*Engineering.*

"The best treatise that has ever been published on steam boilers."—*Engineer.*

Mechanics.

THE HANDBOOK OF MECHANICS. By DIONYSIUS LARDNER, D.C.L. New Edition, Edited and considerably Enlarged, by BENJAMIN LOEWY, F.R.A.S., &c., post 8vo, 6s. cloth.

MATHEMATICS, TABLES, ETC.

Metrical Units and Systems, &c.

MODERN METROLOGY: A Manual of the Metrical Units and Systems of the present Century. With an Appendix containing a proposed English System. By LOWIS D'A. JACKSON, A.-M. Inst. C.E., Author of "Aid to Survey Practice," &c. Large Crown 8vo, 12*s.* 6*d.* cloth. [*Just published.*

Gregory's Practical Mathematics.

MATHEMATICS for PRACTICAL MEN; being a Commonplace Book of Pure and Mixed Mathematics. Designed chiefly for the Use of Civil Engineers, Architects, and Surveyors. Part I. PURE MATHEMATICS—comprising Arithmetic, Algebra, Geometry, Mensuration, Trigonometry, Conic Sections, Properties of Curves. Part II. MIXED MATHEMATICS—comprising Mechanics in general, Statics, Dynamics, Hydrostatics, Hydrodynamics, Pneumatics, Mechanical Agents, Strength of Materials, &c. By OLINTHUS GREGORY, LL.D., F.R.A.S. Enlarged by H. LAW, C.E. 4th Edition, revised by Prof. J. R. YOUNG. With 13 Plates. 8vo, 1*l.* 1*s.* cloth.

Mathematics as applied to the Constructive Arts.

A TREATISE ON MATHEMATICS AS APPLIED TO THE CONSTRUCTIVE ARTS. Illustrating the various processes of Mathematical Investigation by means of Arithmetical and simple Algebraical Equations and Practical Examples, &c. By FRANCIS CAMPIN, C.E. 12mo, 3*s.* 6*d.* cloth. [*Just published.*

Geometry for the Architect, Engineer, &c.

PRACTICAL GEOMETRY, for the Architect, Engineer, and Mechanic. By E. W. TARN, M.A. With Appendices on Diagrams of Strains and Isometrical projection. Demy 8vo, 9*s.* cloth.

The Metric System.

A SERIES OF METRIC TABLES, in which the British Standard Measures and Weights are compared with those of the Metric System at present in use on the Continent. By C. H. DOWLING, C.E. 2nd Edit., revised and enlarged. 8vo, 10*s.* 6*d.* cl.

Inwood's Tables, greatly enlarged and improved.

TABLES FOR THE PURCHASING of ESTATES, Freehold, Copyhold, or Leasehold; Annuities, Advowsons, &c., and for the Renewing of Leases; also for Valuing Reversionary Estates, Deferred Annuities, &c. By WILLIAM INWOOD. 21st edition, with Tables of Logarithms for the more Difficult Computations of the Interest of Money, &c. By M. FÉDOR THOMAN. 12mo. 8*s.* cloth.

"Those interested in the purchase and sale of estates, and in the adjustment of compensation cases, as well as in transactions in annuities, life insurances, &c., will find the present edition of eminent service."—*Engineering.*

Weights, Measures, Moneys, &c.

MEASURES, WEIGHTS, and MONEYS of all NATIONS, and an Analysis of the Christian, Hebrew, and Mahometan Calendars. Entirely New Edition, Revised and Enlarged. By W. S. B. WOOLHOUSE, F.R.A.S. 12mo, 2*s.* 6*d.* cloth boards.

Compound Interest and Annuities.

THEORY of COMPOUND INTEREST and ANNUITIES; with Tables of Logarithms for the more Difficult Computations of Interest, Discount, Annuities, &c., in all their Applications and Uses for Mercantile and State Purposes. By FÉDOR THOMAN, of the Société Crédit Mobilier, Paris. 3rd Edit., 12mo, 4*s.* 6*d.* cl.

Iron and Metal Trades' Calculator.

THE IRON AND METAL TRADES' COMPANION: Being a Calculator containing a Series of Tables upon a new and comprehensive plan for expeditiously ascertaining the value of any goods bought or sold by weight, from 1*s.* per cwt. to 112*s.* per cwt., and from one farthing per lb. to 1*s.* per lb. Each Table extends from one lb. to 100 tons. By T. DOWNIE. 396 pp., 9*s.*, leather.

"Will supply a want, for nothing like it before existed."—*Building News.*

Iron and Steel.

IRON AND STEEL: a Work for the Forge, Foundry, Factory, and Office. Containing Information for Ironmasters and their Stocktakers; Managers of Bar, Rail, Plate, and Sheet Rolling Mills; Iron and Metal Founders; Iron Ship and Bridge Builders; Mechanical, Mining, and Consulting Engineers; Architects, Builders, &c. By CHARLES HOARE, Author of 'The Slide Rule,' &c. Eighth Edition. Oblong 32mo, 6*s.*, leather.

"For comprehensiveness the book has not its equal."—*Iron.*

Comprehensive Weight Calculator.

THE WEIGHT CALCULATOR, being a Series of Tables upon a New and Comprehensive Plan, exhibiting at one Reference the exact Value of any Weight from 1 lb. to 15 tons, at 300 Progressive Rates, from 1 Penny to 168 Shillings per cwt., and containing 186,000 Direct Answers, which, with their Combinations, consisting of a single addition (mostly to be performed at sight), will afford an aggregate of 10,266,000 Answers; the whole being calculated and designed to ensure Correctness and promote Despatch. By HENRY HARBEN, Accountant, Sheffield. New Edition. Royal 8vo, 1*l.* 5*s.*, strongly half-bound.

Comprehensive Discount Guide.

THE DISCOUNT GUIDE: comprising several Series of Tables for the use of Merchants, Manufacturers, Ironmongers, and others, by which may be ascertained the exact profit arising from any mode of using Discounts, either in the Purchase or Sale of Goods, and the method of either Altering a Rate of Discount, or Advancing a Price, so as to produce, by one operation, a sum that will realise any required profit after allowing one or more Discounts: to which are added Tables of Profit or Advance from 1¼ to 90 per cent., Tables of Discount from 1¼ to 98¾ per cent., and Tables of Commission, &c., from ⅛ to 10 per cent. By HENRY HARBEN, Accountant. New Edition. Demy 8vo, 1*l.* 5*s.*, half-bound.

Mathematical Instruments.

MATHEMATICAL INSTRUMENTS: Their Construction, Adjustment, Testing, and Use; comprising Drawing, Measuring, Optical, Surveying, and Astronomical Instruments. By J. F. HEATHER, M.A. Enlarged Edition. 12mo, 5*s.* cloth.

SCIENCE AND ART.

Gold and Gold-Working.

THE GOLDSMITH'S HANDBOOK: containing full instructions for the Alloying and Working of Gold. Including the Art of Alloying, Melting, Reducing, Colouring, Collecting and Refining. Chemical and Physical Properties of Gold, with a new System of Mixing its Alloys; Solders, Enamels, &c. By GEORGE E. GEE. Second Edition, enlarged. 12mo, 3*s*. 6*d*. cloth.

"The best work yet printed on its subject for a reasonable price." —*Jeweller.*

"Essentially a practical manual, well adapted to the wants of amateurs and apprentices, containing trustworthy information that only a practical man can supply."—*English Mechanic.*

Silver and Silver Working.

THE SILVERSMITH'S HANDBOOK, containing full Instructions for the Alloying and Working of Silver. Including the different Modes of Refining and Melting the Metal, its Solders, the Preparation of Imitation Alloys, &c. By G. E. GEE. 12mo, 3*s*. 6*d*.

"The chief merit of the work is its practical character. The workers in the trade will speedily discover its merits when they sit down to study it."—*English Mechanic*

Hall-Marking of Jewellery.

THE HALL-MARKING OF JEWELLERY PRACTICALLY CONSIDERED, comprising an account of all the different Assay Towns of the United Kingdom; with the Stamps at present employed; also the Laws relating to the Standards and Hall-Marks at the various Assay Offices; and a variety of Practical Suggestions concerning the Mixing of Standard Alloys, &c. By GEORGE E. GEE. Crown 8vo, 5*s*. cloth. [*Just published.*

Electro-Plating, &c.

ELECTROPLATING: A Practical Handbook. By J. W. URQUHART, C.E. Crown 8vo, 5*s*. cloth.

"Any ordinarily intelligent person may become an adept in electro-deposition with a very little science indeed, and this is the book to show the way."—*Builder.*

Electrotyping, &c.

ELECTROTYPING: A Practical Manual on the Reproduction and Multiplication of Printing Surfaces and Works of Art by the Electro-deposition of Metals. By J. W. URQUHART, C.E. Crown 8vo, 5*s*. cloth.

"A guide to beginners and those who practise the old and imperfect methods."—*Iron.*

Electro-Plating.

ELECTRO-METALLURGY PRACTICALLY TREATED. BY ALEXANDER WATT, F.R.S.S.A. Including the Electro-Deposition of Copper, Silver, Gold, Brass and Bronze, Platinum, Lead, Nickel, Tin, Zinc, Alloys of Metals, Practical Notes, &c., &c. Eighth Edition, Revised and Enlarged, including the most recent Processes. 12mo, 3*s*. 6*d*. cloth. [*Just published.*

"From this book both amateur and artisan may learn everything necessary for the successful prosecution of electroplating."—*Iron.*

"A practical treatise for the use of those who desire to work in the art of electro-deposition as a business."—*English Mechanic.*

Dentistry.

MECHANICAL DENTISTRY. A Practical Treatise on the Construction of the various kinds of Artificial Dentures. Comprising also Useful Formulæ, Tables, and Receipts for Gold Plate, Clasps, Solders, etc., etc. By CHARLES HUNTER. Second Edition, Revised; including a new chapter on the use of Celluloid. With over 100 Engravings. Cr. 8vo, 7*s.* 6*d.* cl. [*Just published.*

"An authoritative treatise, which we can strongly recommend to all students."—*Dublin Journal of Medical Science.*

"The best book on the subject with which we are acquainted."—*Medical Press.*

Electricity.

A MANUAL of ELECTRICITY; including Galvanism, Magnetism, Diamagnetism, Electro-Dynamics, Magneto-Electricity, and the Electric Telegraph. By HENRY M. NOAD, Ph.D., F.C.S. Fourth Edition, with 500 Woodcuts. 8vo, 1*l.* 4*s.* cloth.

"The accounts given of electricity and galvanism are not only complete in a scientific sense, but, which is a rarer thing, are popular and interesting."—*Lancet.*

Text-Book of Electricity.

THE STUDENT'S TEXT-BOOK OF ELECTRICITY. By HENRY M. NOAD, Ph.D., F.R.S., &c. New Edition, Revised. With an Introduction and Additional Chapters by W. H. PREECE, M.I.C.E., Vice-President of the Society of Telegraph Engineers, &c. With 470 Illustrations. Crown 8vo, 12*s.* 6*d.* cloth.

"A reflex of the existing state of Electrical Science adapted for students."—W. H. Preece, Esq., vide "Introduction."

"We can recommend Dr. Noad's book for clear style, great range of subject, a good index, and a plethora of woodcuts. Such collections as the present are indispensable."—*Athenæum.*

"An admirable text-book for every student—beginner or advanced—of electricity." —*Engineering.*

"Recommended to students as one of the best text-books on the subject that they can have. Mr. Preece appears to have introduced all the newest inventions in the shape of telegraphic, telephonic, and electric-lighting apparatus."—*English Mechanic.*

"Under the editorial hand of Mr. Preece the late Dr. Noad's text-book of electricity has grown into an admirable handbook."—*Westminster Review.*

Electric Lighting.

ELECTRIC LIGHT: Its Production and Use, embodying plain Directions for the Working of Galvanic Batteries, Electric Lamps, and Dynamo-Electric Machines. By J. W. URQUHART, C.E., Author of "Electroplating." Edited by F. C. WEBB, M.I.C.E., M.S.T.E. With 94 Illustrations. Crown 8vo, 7*s.* 6*d.* cloth.

"The book is by far the best that we have yet met with on the subject."—*Athenæum.*

"An important addition to the literature of the electric light. Students of the subject should not fail to read it."—*Colliery Guardian.*

Lightning, &c.

THE ACTION of LIGHTNING, and the MEANS of DEFENDING LIFE AND PROPERTY FROM ITS EFFECTS. By ARTHUR PARNELL, Major in the Corps of Royal Engineers. 12mo, 7*s.* 6*d.* cloth. [*Just published.*

"Major Parnell has written an original work on a scientific subject of unusual interest; and he has prefaced his arguments by a patient and almost exhaustive citation of the best writers on the subject in the English language."—*Athenæum.*

"The work comprises all that is actually known on the subject."—*Land.*

"Major Parnell's measures are based on the results of experience. A valuable *repertoire* of facts and principles arranged in a scientific form."—*Building News.*

The Alkali Trade—Sulphuric Acid, &c.

A MANUAL OF THE ALKALI TRADE, including the Manufacture of Sulphuric Acid, Sulphate of Soda, and Bleaching Powder. By JOHN LOMAS, Alkali Manufacturer, Newcastle-upon-Tyne and London. With 232 Illustrations and Working Drawings, and containing 386 pages of text. Super-royal 8vo, 2*l.* 12*s.* 6*d.* cloth.

This work provides (1) *a Complete Handbook for intending Alkali and Sulphuric Acid Manufacturers, and for those already in the field who desire to improve their plant, or to become practically acquainted with the latest processes and developments of the trade;* (2) *a Handy Volume which Manufacturers can put into the hands of their Managers and Foremen as a useful guide in their daily rounds of duty.*

SYNOPSIS OF CONTENTS.

Chap. I. Choice of Site and General Plan of Works—II. Sulphuric Acid—III. Recovery of the Nitrogen Compounds, and Treatment of Small Pyrites—IV. The Salt Cake Process—V. Legislation upon the Noxious Vapours Question—VI. The Hargreaves' and Jones' Processes—VII. The Balling Process—VIII. Lixiviation and Salting Down—IX. Carbonating or Finishing—X. Soda Crystals—XI. Refined Alkali—XII. Caustic Soda—XIII. Bi-carbonate of Soda—XIV. Bleaching Powder—XV. Utilisation of Tank Waste—XVI. General Remarks—Four Appendices, treating of Yields, Sulphuric Acid Calculations, Anemometers, and Foreign Legislation upon the Noxious Vapours Question.

"The author has given the fullest, most practical, and, to all concerned in the alkali trade, most valuable mass of information that, to our knowledge, has been published in any language."—*Engineer.*

"This book is written by a manufacturer for manufacturers. The working details of the most approved forms of apparatus are given, and these are accompanied by no less than 232 wood engravings, all of which may be used for the purposes of construction. Every step in the manufacture is very fully described in this manual, and each improvement explained. Everything which tends to introduce economy into the technical details of this trade receives the fullest attention. The book has been produced with great completeness."—*Athenæum.*

"The author is not one of those clever compilers who, on short notice, will 'read up' any conceivable subject, but a practical man in the best sense of the word. We find here not merely a sound and luminous explanation of the chemical principles of the trade, but a notice of numerous matters which have a most important bearing on the successful conduct of alkali works, but which are generally overlooked by even the most experienced technological authors. This most valuable book, which we trust will be generally appreciated, we must pronounce a credit alike to its author and to the enterprising firm who have undertaken its publication."—*Chemical Review.*

Chemical Analysis.

THE COMMERCIAL HANDBOOK of CHEMICAL ANALYSIS; or Practical Instructions for the determination of the Intrinsic or Commercial Value of Substances used in Manufactures, in Trades, and in the Arts. By A. NORMANDY, Author of "Practical Introduction to Rose's Chemistry," and Editor of Rose's "Treatise on Chemical Analysis." *New Edition.* Enlarged, and to a great extent re-written, by HENRY M. NOAD, Ph. D., F.R.S. With numerous Illustrations. Cr. 8vo, 12*s.* 6*d.* cloth.

"We recommend this book to the careful perusal of every one; it may be truly affirmed to be of universal interest, and we strongly recommend it to our readers as a guide, alike indispensable to the housewife as to the pharmaceutical practitioner."—*Medical Times.*

"Essential to the analysts appointed under the new Act. The most recent results are given, and the work is well edited and carefully written."—*Nature.*

Dr. Lardner's Museum of Science and Art.

THE MUSEUM OF SCIENCE AND ART. Edited by DIONYSIUS LARDNER, D.C.L., formerly Professor of Natural Philosophy and Astronomy in University College, London. With upwards of 1200 Engravings on Wood. In 6 Double Volumes. Price £1 1*s.*, in a new and elegant cloth binding, or handsomely bound in half morocco, 31*s.* 6*d.*

OPINIONS OF THE PRESS.

"This series, besides affording popular but sound instruction on scientific subjects, with which the humblest man in the country ought to be acquainted, also undertakes that teaching of 'common things' which every well-wisher of his kind is anxious to promote. Many thousand copies of this serviceable publication have been printed, in the belief and hope that the desire for instruction and improvement widely prevails; and we have no fear that such enlightened faith will meet with disappointment."—*Times.*

"A cheap and interesting publication, alike informing and attractive. The papers combine subjects of importance and great scientific knowledge, considerable inductive powers, and a popular style of treatment."—*Spectator.*

"The 'Museum of Science and Art' is the most valuable contribution that has ver been made to the Scientific Instruction of every class of society."—*Sir David Brewster in the North British Review.*

"Whether we consider the liberality and beauty of the illustrations, the charm of the writing, or the durable interest of the matter, we must express our belief that there is hardly to be found among the new books, one that would be welcomed by people of so many ages and classes as a valuable present."—*Examiner.*

*** *Separate books formed from the above, suitable for Workmen's Libraries, Science Classes, &c.*

COMMON THINGS EXPLAINED. Containing Air, Earth, Fire, Water, Time, Man, the Eye, Locomotion, Colour, Clocks and Watches, &c. 233 Illustrations, cloth gilt, 5*s.*

THE MICROSCOPE. Containing Optical Images, Magnifying Glasses, Origin and Description of the Microscope, Microscopic Objects, the Solar Microscope, Microscopic Drawing and Engraving, &c. 147 Illustrations, cloth gilt, 2*s.*

POPULAR GEOLOGY. Containing Earthquakes and Volcanoes, the Crust of the Earth, etc. 201 Illustrations, cloth gilt, 2*s.* 6*d.*

POPULAR PHYSICS. Containing Magnitude and Minuteness, the Atmosphere, Meteoric Stones, Popular Fallacies, Weather Prognostics, the Thermometer, the Barometer, Sound, &c. 85 Illustrations, cloth gilt, 2*s.* 6*d.*

STEAM AND ITS USES. Including the Steam Engine, the Locomotive, and Steam Navigation. 89 Illustrations, cloth gilt, 2*s.*

POPULAR ASTRONOMY. Containing How to Observe the Heavens. The Earth, Sun, Moon, Planets. Light, Comets, Eclipses, Astronomical Influences, &c. 182 Illustrations, 4*s.* 6*d.*

THE BEE AND WHITE ANTS: Their Manners and Habits. With Illustrations of Animal Instinct and Intelligence. 135 Illustrations, cloth gilt, 2*s.*

THE ELECTRIC TELEGRAPH POPULARISED. To render intelligible to all who can Read, irrespective of any previous Scientific Acquirements, the various forms of Telegraphy in Actual Operation. 100 Illustrations, cloth gilt, 1*s.* 6*d.*

Dr. Lardner's Handbooks of Natural Philosophy.

**** The following five volumes, though each is Complete in itself, and to be purchased separately, form* A Complete Course of Natural Philosophy, *and are intended for the general reader who desires to attain accurate knowledge of the various departments of Physical Science, without pursuing them according to the more profound methods of mathematical investigation. The style is studiously popular. It has been the author's aim to supply Manuals such as are required by the Student, the Engineer, the Artisan, and the superior classes in Schools.*

THE HANDBOOK OF MECHANICS. Enlarged and almost rewritten by BENJAMIN LOEWY, F.R.A.S. With 378 Illustrations. Post 8vo, 6*s.* cloth.

"The perspicuity of the original has been retained, and chapters which had become obsolete, have been replaced by others of more modern character. The explanations throughout are studiously popular, and care has been taken to show the application of the various branches of physics to the industrial arts, and to the practical business of life."—*Mining Journal.*

THE HANDBOOK of HYDROSTATICS and PNEUMATICS. New Edition, Revised and Enlarged by BENJAMIN LOEWY, F.R.A.S. With 236 Illustrations. Post 8vo, 5*s.* cloth.

"For those 'who desire to attain an accurate knowledge of physical science without the profound methods of mathematical investigation,' this work is not merely intended, but well adapted."—*Chemical News.*

THE HANDBOOK OF HEAT. Edited and almost entirely Rewritten by BENJAMIN LOEWY, F.R.A.S., etc. 117 Illustrations. Post 8vo, 6*s.* cloth.

"The style is always clear and precise, and conveys instruction without leaving any cloudiness or lurking doubts behind."—*Engineering.*

THE HANDBOOK OF OPTICS. New Edition. Edited by T. OLVER HARDING, B.A. 298 Illustrations. Post 8vo, 5*s.* cloth.

"Written by one of the ablest English scientific writers, beautifully and elaborately illustrated."—*Mechanics' Magazine.*

THE HANDBOOK OF ELECTRICITY, MAGNETISM, and ACOUSTICS. New Edition. Edited by GEO. CAREY FOSTER, B.A., F.C.S. With 400 Illustrations. Post 8vo, 5*s.* cloth.

"The book could not have been entrusted to any one better calculated to preserve the terse and lucid style of Lardner, while correcting his errors and bringing up his work to the present state of scientific knowledge."—*Popular Science Review.*

Dr. Lardner's Handbook of Astronomy.

THE HANDBOOK OF ASTRONOMY. Forming a Companion to the "Handbooks of Natural Philosophy." By DIONYSIUS LARDNER, D.C.L. Fourth Edition. Revised and Edited by EDWIN DUNKIN, F.R.S., Royal Observatory, Greenwich. With 38 Plates and upwards of 100 Woodcuts. In 1 vol., small 8vo, 550 pages, 9*s.* 6*d.*, cloth.

"Probably no other book contains the same amount of information in so compendious and well-arranged a form—certainly none at the price at which this is offered to the public."—*Athenæum.*

"We can do no other than pronounce this work a most valuable manual of astronomy, and we strongly recommend it to all who wish to acquire a general—but at the same time correct—acquaintance with this sublime science."—*Quarterly Journal of Science.*

Dr. Lardner's Handbook of Animal Physics.

THE HANDBOOK OF ANIMAL PHYSICS. By DR. LARDNER. With 520 Illustrations. New edition, small 8vo, cloth, 732 pages, 7*s.* 6*d.*

"We have no hesitation in cordially recommending it."—Educational Times.

Dr. Lardner's School Handbooks.

NATURAL PHILOSOPHY FOR SCHOOLS. By DR. LARDNER. 328 Illustrations. Sixth Edition. 1 vol. 3*s.* 6*d.* cloth.

"Conveys, in clear and precise terms, general notions of all the principal divisions of Physical Science."—*British Quarterly Review.*

ANIMAL PHYSIOLOGY FOR SCHOOLS. By DR. LARDNER. With 190 Illustrations. Second Edition. 1 vol. 3*s.* 6*d.* cloth.

"Clearly written, well arranged, and excellently illustrated."—*Gardeners' Chronicle.*

Dr. Lardner's Electric Telegraph.

THE ELECTRIC TELEGRAPH. By DR. LARDNER. New Edition. Revised and Re-written, by E. B. BRIGHT, F.R.A.S. 140 Illustrations. Small 8vo, 2*s.* 6*d.* cloth.

"One of the most readable books extant on the Electric Telegraph."—*Eng. Mechanic.*

Mollusca.

A MANUAL OF THE MOLLUSCA; being a Treatise on Recent and Fossil Shells. By Dr. S. P. WOODWARD, A.L.S. With Appendix by RALPH TATE, A.L.S., F.G.S. With numerous Plates and 300 Woodcuts. 3rd Edition. Cr. 8vo, 7*s.* 6*d.* cloth.

Geology and Genesis.

THE TWIN RECORDS OF CREATION; or, Geology and Genesis, their Perfect Harmony and Wonderful Concord. By GEORGE W. VICTOR LE VAUX. Fcap. 8vo, 5*s.* cloth.

"A valuable contribution to the evidences of revelation, and disposes very conclusively of the arguments of those who would set God's Works against God's Word. No real difficulty is shirked, and no sophistry is left unexposed."—*The Rock.*

Science and Scripture.

SCIENCE ELUCIDATIVE OF SCRIPTURE, AND NOT ANTAGONISTIC TO IT; being a Series of Essays on—1. Alleged Discrepancies; 2. The Theory of the Geologists and Figure of the Earth; 3. The Mosaic Cosmogony; 4. Miracles in general—Views of Hume and Powell; 5. The Miracle of Joshua—Views of Dr. Colenso, &c. By Prof. J. R. YOUNG. Fcap. 5*s.* cloth.

Geology.

A CLASS-BOOK OF GEOLOGY: Consisting of "Physical Geology," which sets forth the Leading Principles of the Science; and "Historical Geology," which treats of the Mineral and Organic Conditions of the Earth at each successive epoch, especial reference being made to the British Series of Rocks. By RALPH TATE. With more than 250 Illustrations. Fcap. 8vo, 5*s.* cloth.

Practical Philosophy.

A SYNOPSIS OF PRACTICAL PHILOSOPHY. By Rev. JOHN CARR, M.A., late Fellow of Trin. Coll., Camb. 18mo, 5*s.* cl.

Pictures and Painters.

THE PICTURE AMATEUR'S HANDBOOK AND DICTIONARY OF PAINTERS: A Guide for Visitors to Picture Galleries, and for Art-Students, including methods of Painting, Cleaning, Re-Lining, and Restoring, Principal Schools of Painting, Copyists and Imitators. By PHILIPPE DARYL, B.A. Cr. 8vo, 3*s.* 6*d.* cl.

Clocks, Watches, and Bells.

RUDIMENTARY TREATISE on CLOCKS, and WATCHES, and BELLS. By Sir EDMUND BECKETT, Bart. (late E. B. Denison), LL.D., Q.C., F.R.A.S. Sixth Edition, revised and enlarged. Limp cloth (No. 67, Weale's Series), 4*s*. 6*d*.; cloth bds. 5*s*. 6*d*.

"The best work on the subject probably extant. The treatise on bells is undoubtedly the best in the language."—*Engineering*.

"The only modern treatise on clock-making."—*Horological Journal*.

The Construction of the Organ.

PRACTICAL ORGAN-BUILDING. By W. E. DICKSON, M.A., Precentor of Ely Cathedral. Second Edition, revised, with Additions. 12mo, 3*s*. cloth boards. [*Just published*.

"In many respects the book is the best that has yet appeared on the subject. We cordially recommend it."—*English Mechanic*.

"The amateur builder will find in this book all that is necessary to enable him personally to construct a perfect organ with his own hands."—*Academy*.

Brewing.

A HANDBOOK FOR YOUNG BREWERS. By HERBERT EDWARDS WRIGHT, B.A. Crown 8vo, 3*s*. 6*d*. cloth.

"A thoroughly scientific treatise in popular language."—*Morning Advertiser*.

"We would particularly recommend teachers of the art to place it in every pupil's hands, and we feel sure its perusal will be attended with advantage."—*Brewer*.

Dye-Wares and Colours.

THE MANUAL of COLOURS and DYE-WARES: their Properties, Applications, Valuation, Impurities, and Sophistications. For the Use of Dyers, Printers, Drysalters, Brokers, &c. By J. W. SLATER. Second Edition. Re-written and Enlarged. Crown 8vo, 7*s*. 6*d*. cloth. [*Just published*.

Grammar of Colouring.

A GRAMMAR OF COLOURING, applied to Decorative Painting and the Arts. By GEORGE FIELD. New edition. By ELLIS A. DAVIDSON. 12mo, 3*s*. 6*d*. cloth.

Woods and Marbles (Imitation of).

SCHOOL OF PAINTING FOR THE IMITATION OF WOODS AND MARBLES, as Taught and Practised by A. R. and P. VAN DER BURG. With 24 full-size Coloured Plates; also 12 Plain Plates, comprising 154 Figures. Folio, 2*l*. 12*s*. 6*d*. bound.

The Military Sciences.

AIDE-MÉMOIRE to the MILITARY SCIENCES. Framed from Contributions of Officers and others connected with the different Services. Originally edited by a Committee of the Corps of Royal Engineers. 2nd Edition, revised; nearly 350 Engravings and many hundred Woodcuts. 3 vols. royal 8vo, cloth, 4*l*. 10*s*.

Field Fortification.

A TREATISE on FIELD FORTIFICATION, the ATTACK of FORTRESSES, MILITARY MINING, and RECONNOITRING. By Colonel I. S. MACAULAY, late Professor of Fortification in the R. M. A., Woolwich. Sixth Edition, crown 8vo, cloth, with separate Atlas of 12 Plates, 12*s*. complete.

Delamotte's Works on Illumination & Alphabets.

A PRIMER OF THE ART OF ILLUMINATION; for the use of Beginners: with a Rudimentary Treatise on the Art, Practical Directions for its Exercise, and numerous Examples taken from Illuminated MSS., printed in Gold and Colours. By F. DELAMOTTE. Small 4to, 9*s*. Elegantly bound, cloth antique.

"The examples of ancient MSS. recommended to the student, which, with much good sense, the author chooses from collections accessible to all, are selected with judgment and knowledge, as well as taste."—*Athenæum.*

ORNAMENTAL ALPHABETS, ANCIENT and MEDIÆVAL; from the Eighth Century, with Numerals; including Gothic, Church-Text, German, Italian, Arabesque, Initials, Monograms, Crosses, &c. Collected and engraved by F. DELAMOTTE, and printed in Colours. New and Cheaper Edition. Royal 8vo, oblong, 2*s*. 6*d*. ornamental boards.

"For those who insert enamelled sentences round gilded chalices, who blazon shop legends over shop-doors, who letter church walls with pithy sentences from the Decalogue, this book will be useful."—*Athenæum.*

EXAMPLES OF MODERN ALPHABETS, PLAIN and ORNAMENTAL; including German, Old English, Saxon, Italic, Perspective, Greek, Hebrew, Court Hand, Engrossing, Tuscan, Riband, Gothic, Rustic, and Arabesque, &c., &c. Collected and engraved by F. DELAMOTTE, and printed in Colours. New and Cheaper Edition. Royal 8vo, oblong, 2*s*. 6*d*. ornamental boards.

"There is comprised in it every possible shape into which the letters of the alphabet and numerals can be formed."—*Standard.*

MEDIÆVAL ALPHABETS AND INITIALS FOR ILLUMINATORS. By F. DELAMOTTE. Containing 21 Plates, and Illuminated Title, printed in Gold and Colours. With an Introduction by J. WILLIS BROOKS. Small 4to, 6*s*. cloth gilt.

THE EMBROIDERER'S BOOK OF DESIGN; containing Initials, Emblems, Cyphers, Monograms, Ornamental Borders, Ecclesiastical Devices, Mediæval and Modern Alphabets, and National Emblems. Collected and engraved by F. DELAMOTTE, and printed in Colours. Oblong royal 8vo, 1*s*. 6*d*. ornamental wrapper.

Wood-Carving.

INSTRUCTIONS in WOOD-CARVING, for Amateurs; with Hints on Design. By A LADY. In emblematic wrapper, handsomely printed, with Ten large Plates, 2*s*. 6*d*.

"The handicraft of the wood-carver, so well as a book can impart it, may be learnt from 'A Lady's' publication."—*Athenæum.*

Popular Work on Painting.

PAINTING POPULARLY EXPLAINED; with Historical Sketches of the Progress of the Art. By THOMAS JOHN GULLICK, Painter, and JOHN TIMBS, F.S.A. Fourth Edition, revised and enlarged. With Frontispiece and Vignette. In small 8vo, 5*s*. 6*d*. cloth.

*** *This Work has been adopted as a Prize-book in the Schools of Art at South Kensington.*

"Contains a large amount of original matter, agreeably conveyed."—*Builder.*

"*Much may be learned, even by those who fancy they do not require to be taught, from the careful perusal of this unpretending but comprehensive treatise.*"—*Art Journal.*

AGRICULTURE, GARDENING, ETC.

Youatt and Burn's Complete Grazier.

THE COMPLETE GRAZIER, and FARMER'S and CATTLE-BREEDER'S ASSISTANT. A Compendium of Husbandry. By WILLIAM YOUATT, ESQ., V.S. 12th Edition, very considerably enlarged, and brought up to the present requirements of agricultural practice. By ROBERT SCOTT BURN. One large 8vo. volume, 860 pp. with 244 Illustrations. 1*l.* 1*s.* half-bound.

"The standard and text-book, with the farmer and grazier."—*Farmer's Magazine.*

"A treatise which will remain a standard work on the subject as long as British agriculture endures."—*Mark Lane Express.*

History, Structure, and Diseases of Sheep.

SHEEP; THE HISTORY, STRUCTURE, ECONOMY, AND DISEASES OF. By W. C. SPOONER, M.R.V.C., &c. Fourth Edition, with fine engravings, including specimens of New and Improved Breeds. 366 pp., 4*s.* cloth.

Production of Meat.

MEAT PRODUCTION. A Manual for Producers, Distributors, and Consumers of Butchers' Meat. Being a treatise on means of increasing its Home Production. Also treating of the Breeding, Rearing, Fattening, and Slaughtering of Meat-yielding Live Stock; Indications of the Quality, etc. By JOHN EWART. Cr. 8vo, 5*s.* cloth.

"A compact and handy volume on the meat question, which deserves serious and thoughtful consideration at the present time."—*Meat and Provision Trades' Review.*

Donaldson and Burn's Suburban Farming.

SUBURBAN FARMING. A Treatise on the Laying Out and Cultivation of Farms adapted to the produce of Milk, Butter and Cheese, Eggs, Poultry, and Pigs. By the late Professor JOHN DONALDSON. With Additions, Illustrating the more Modern Practice, by R. SCOTT BURN. 12mo, 4*s.* cloth boards.

English Agriculture.

THE FIELDS OF GREAT BRITAIN. A Text-book of Agriculture, adapted to the Syllabus of the Science and Art Department. For Elementary and Advanced Students. By HUGH CLEMENTS (Board of Trade). With an Introduction by H. KAINS-JACKSON. 18mo, 2*s.* 6*d.* cloth.

"A clearly written description of the ordinary routine of English farm-life."—*Land.*

"A carefully written text-book of Agriculture."—*Athenæum.*

"A most comprehensive volume, giving a mass of information."—*Agricultural* [*Economist.*

Modern Farming.

OUTLINES OF MODERN FARMING. By R. SCOTT BURN. Soils, Manures, and Crops—Farming and Farming Economy—Cattle, Sheep, and Horses—Management of the Dairy, Pigs, and Poultry—Utilisation of Town Sewage, Irrigation, &c. New Edition. In 1 vol. 1250 pp., half-bound, profusely illustrated, 12*s.*

"There is sufficient stated within the limits of this treatise to prevent a farmer from going far wrong in any of his operations."—*Observer.*

The Management of Estates.

LANDED ESTATES MANAGEMENT: Treating of the Varieties of Lands, Methods of Farming, Farm Building, Irrigation, Drainage, &c. By R. SCOTT BURN. 12mo, 3s. cloth.

"A complete and comprehensive outline of the duties appertaining to the management of landed estates."—*Journal of Forestry.*

The Management of Farms.

OUTLINES OF FARM MANAGEMENT, and the Organization of Farm Labour. Treating of the General Work of the Farm, Field, and Live Stock, Details of Contract Work, Specialties of Labour, Economical Management of the Farmhouse and Cottage, Domestic Animals, &c. By ROBERT SCOTT BURN. 12mo, 3s.

Management of Estates and Farms.

LANDED ESTATES AND FARM MANAGEMENT. By R. SCOTT BURN. (The above Two Works in One Vol.) 6s.

Hudson's Tables for Land Valuers.

THE LAND VALUER'S BEST ASSISTANT: being Tables, on a very much improved Plan, for Calculating the Value of Estates. With Tables for reducing Scotch, Irish, and Provincial Customary Acres to Statute Measure, &c. By R. HUDSON, C.E. New Edition, royal 32mo, leather, gilt edges, elastic band, 4s.

Ewart's Land Improver's Pocket-Book.

THE LAND IMPROVER'S POCKET-BOOK OF FORMULÆ, TABLES, and MEMORANDA, required in any Computation relating to the Permanent Improvement of Landed Property. By JOHN EWART, Land Surveyor. 32mo, leather, 4s.

Complete Agricultural Surveyor's Pocket-Book.

THE LAND VALUER'S AND LAND IMPROVER'S COMPLETE POCKET-BOOK; consisting of the above two works bound together, leather, gilt edges, with strap, 7s. 6d.

"We consider Hudson's book to be the best ready-reckoner on matters relating to the valuation of land and crops we have ever seen, and its combination with Mr. Ewart's work greatly enhances the value and usefulness of the latter-mentioned.—It is most useful as a manual for reference."—*North of England Farmer.*

Grafting and Budding.

THE ART OF GRAFTING AND BUDDING. By CHARLES BALTET. Translated from the French. With upwards of 180 Illustrations. 12mo, 3s. cloth boards. [*Just published.*

Culture of Fruit Trees.

FRUIT TREES, the Scientific and Profitable Culture of. Including Choice of Trees, Planting, Grafting, Training, Restoration of Unfruitful Trees, &c. From the French of DU BREUIL. Third Edition, revised. With an Introduction by GEORGE GLENNY. 4s. cl.

"The book teaches how to prune and train fruit-trees to perfection."—*Field.*

Potato Culture.

POTATOES, HOW TO GROW AND SHOW THEM: A *Practical Guide to the Cultivation and General Treatment of the Potato.* By JAMES PINK. With Illustrations. Cr. 8vo, 2s. cl.

Good Gardening.

A PLAIN GUIDE TO GOOD GARDENING; or, How to Grow Vegetables, Fruits, and Flowers. With Practical Notes on Soils, Manures, Seeds, Planting, Laying-out of Gardens and Grounds, &c. By S. WOOD. Third Edition. Cr. 8vo, 5*s*. cloth.

"A very good book, and one to be highly recommended as a practical guide. The practical directions are excellent."—*Athenæum.*

Gainful Gardening.

MULTUM-IN-PARVO GARDENING; or, How to make One Acre of Land produce £620 a year, by the Cultivation of Fruits and Vegetables; also, How to Grow Flowers in Three Glass Houses, so as to realise £176 per annum clear Profit. By SAMUEL WOOD. 3rd Edition, revised. Cr. 8vo, 2*s*. cloth.

"We are bound to recommend it as not only suited to the case of the amateur and gentleman's gardener, but to the market grower."—*Gardener's Magazine.*

Gardening for Ladies.

THE LADIES' MULTUM-IN-PARVO FLOWER GARDEN, and Amateur's Complete Guide. By S. WOOD. Cr. 8vo, 3*s*. 6*d*.

Bulb Culture.

THE BULB GARDEN, or, How to Cultivate Bulbous and Tuberous-rooted Flowering Plants to Perfection. By SAMUEL WOOD. Coloured Plates. Crown 8vo, 3*s*. 6*d*. cloth.

Tree Planting.

THE TREE PLANTER AND PLANT PROPAGATOR: A Practical Manual on the Propagation of Forest Trees, Fruit Trees, Flowering Shrubs, Flowering Plants, Pot Herbs, &c. Numerous Illustrations. By SAMUEL WOOD. 12mo, 2*s*. 6*d*. cloth.

Tree Pruning.

THE TREE PRUNER: A Practical Manual on the Pruning of Fruit Trees, their Training and Renovation; also the Pruning of Shrubs, Climbers, &c. By S. WOOD. 12mo, 2*s*. 6*d*. cloth.

Tree Planting, Pruning, & Plant Propagation.

THE TREE PLANTER, PROPAGATOR, AND PRUNER. By SAMUEL WOOD, Author of "Good Gardening," &c. Consisting of the above Two Works in One Vol., 5*s*. half-bound.

Early Fruits, Flowers and Vegetables.

THE FORCING GARDEN: or, How to Grow Early Fruits, Flowers, and Vegetables. With Plans and Estimates for Building Glasshouses, Pits, Frames, &c. By S. WOOD. Crown 8vo, 3*s*. 6*d*.

Market Gardening, Etc.

THE KITCHEN AND MARKET GARDEN. By Contributors to "The Garden." Compiled by C. W. SHAW, Editor of "Gardening Illustrated." 12mo, 3*s*. 6*d*. cl. bds. [*Just published.*

Kitchen Gardening.

KITCHEN GARDENING MADE EASY. Showing how to prepare and lay out the ground, the best means of cultivating every known Vegetable and Herb, etc. By G. M. F. GLENNY. 12mo, 2s.

'A Complete Epitome of the Laws of this Country.'

EVERY MAN'S OWN LAWYER; a Handy-Book of the Principles of Law and Equity. By A BARRISTER. New Edition. Corrected to the end of last Session. Embracing upwards of 3,500 Statements on Points of Law, Verified by the addition of Notes and References to the Authorities. Crown 8vo, cloth, price 6*s.* 8*d.* (saved at every consultation).

COMPRISING THE RIGHTS AND WRONGS OF INDIVIDUALS, MERCANTILE AND COMMERCIAL LAW, CRIMINAL LAW, PARISH LAW, COUNTY COURT LAW, GAME AND FISHERY LAWS, POOR MEN'S LAW, THE LAWS OF

BANKRUPTCY—BILLS OF EXCHANGE—CONTRACTS AND AGREEMENTS—COPYRIGHT—DOWER AND DIVORCE—ELECTIONS AND REGISTRATION—INSURANCE—LIBEL AND SLANDER—MORTGAGES—SETTLEMENTS—STOCK EXCHANGE PRACTICE—TRADE MARKS AND PATENTS—TRESPASS, NUISANCES, ETC.—TRANSFER OF LAND, ETC. — WARRANTY — WILLS AND AGREEMENTS, ETC.

Also Law for Landlord and Tenant—Master and Servant—Workmen and Apprentices—Heirs, Devisees, and Legatees — Husband and Wife — Executors and Trustees — Guardian and Ward — Married Women and Infants—Partners and Agents — Lender and Borrower — Debtor and Creditor — Purchaser and Vendor — Companies and Associations —Friendly Societies—Clergymen, Churchwardens—Medical Practitioners, &c. — Bankers — Farmers — Contractors—Stock and Share Brokers—Sportsmen and Gamekeepers—Farriers and Horse-Dealers—Auctioneers, House-Agents—Innkeepers, &c.— Pawnbrokers — Surveyors — Railways and Carriers, &c., &c.

"No Englishman ought to be without this book."—*Engineer.*

"What it professes to be—a complete epitome of the laws of this country, thoroughly intelligible to non-professional readers. The book is a handy one to have in readiness when some knotty point requires ready solution."—*Bell's Life.*

"A useful and concise epitome of the law."—*Law Magazine.*

Auctioneer's Assistant.

THE APPRAISER, AUCTIONEER, BROKER, HOUSE AND ESTATE AGENT, AND VALUER'S POCKET ASSISTANT, for the Valuation for Purchase, Sale, or Renewal of Leases, Annuities, and Reversions, and of property generally; with Prices for Inventories, &c. By JOHN WHEELER, Valuer, &c. Fourth Edition, enlarged, by C. NORRIS. Royal 32mo, cloth, 5*s.*

"A concise book of reference, containing a clearly-arranged list of prices for inventories, a practical guide to determine the value of furniture, &c."—*Standard.*

Auctioneering.

AUCTIONEERS: THEIR DUTIES AND LIABILITIES. By ROBERT SQUIBBS, Auctioneer. Demy 8vo, 10*s.* 6*d.* cloth.

"Every auctioneer and valuer ought to possess a copy of this valuable work."—*Ironmonger.*

House Property.

HANDBOOK OF HOUSE PROPERTY: a Popular and Practical Guide to the Purchase, Mortgage, Tenancy, and Compulsory Sale of Houses and Land; including the Law of Dilapidations and Fixtures, &c. By E. L. TARBUCK. 2nd Edit. 12mo, 3*s.* 6*d.* cloth.

"We are glad to be able to recommend it."—*Builder.*

"The advice is thoroughly practical."—*Law Journal.*

Metropolitan Rating.

METROPOLITAN RATING: a Summary of the Appeals heard before the Court of General Assessment Sessions at Westminster, in the years 1871–80 inclusive. Containing a large mass of very valuable information with respect to the Rating of Railways, Gas and Waterworks, Tramways, Wharves, Public Houses, &c. By EDWARD and A. L. RYDE. 8vo, 12*s.* 6*d.*

Bradbury, Agnew, & Co., Printers, Whitefriars, London.

MECHANICAL ENGINEERING, &c.

MECHANICAL ENGINEERING, A Practical Treatise on. Comprising Metallurgy, Moulding, Casting, Forging, Tools, Workshop Machinery, Mechanical Manipulation, Manufacture of the Steam Engine, &c. By FRANCIS CAMPIN, C.E. 2s. 6d.; cloth boards, 3s.

MATERIALS AND CONSTRUCTION: a Theoretical and Practical Treatise on the Strains, Designing, and Erection of Works of Construction. By FRANCIS CAMPIN, C.E. 3s.; cloth boards, 3s. 6d.

THE BOILERMAKERS' ASSISTANT, in Drawing, Templating, and Calculating Boiler and Tank Work. By JOHN COURTNEY, Practical Boilermaker. Revised and Edited by D. KINNEAR CLARK, M.I.C.E. 2s.

SEWING MACHINERY. A Practical Manual of the Sewing Machine, comprising its History and Details of its Construction, with full technical directions for the adjusting of Sewing Machines. By J. W. URQUHART, C.E. 2s.; cloth boards, 2s. 6d.

MECHANICS; being a concise Exposition of the General Principles of Mechanical Science, and their Applications. By C. TOMLINSON. Illustrated. 1s. 6d.

THE STEAM ENGINE. By Dr. LARDNER. 1s. 6d.

THE STEAM ENGINE, the Mathematical Theory of, with Rules at length, and Examples for the use of Practical Men. By T. BAKER, C.E. Illustrated. 1s. 6d.

STEAM BOILERS: their Construction and Management. By R. ARMSTRONG, C.E. Illustrated. 1s. 6d.

CLOCKS, WATCHES, AND BELLS. By Sir EDMUND BECKETT (late E. B. DENISON, LL.D., &c., &c.). A New Edition, revised. 4s. 6d.; cloth boards, 5s. 6d.

FUEL, its Combustion and Economy. By C. W. WILLIAMS, A.I.C.E. With extensive additions on Recent Practice in the Combustion and Economy of Fuel—Coal, Coke, Wood, Peat, Petroleum, &c., by D. KINNEAR CLARK, M.I.C.E. Second Edition. 3s. 6d.; cloth boards, 4s.

MARINE ENGINES AND STEAM VESSELS, With Practical Remarks on the Screw and Propelling Power, as used in the Royal and Merchant Navy. By ROBERT MURRAY, C.E. 7th Edition. 3s.; cloth boards, 3s. 6d.

STEAM AND THE STEAM ENGINE, Stationary and Portable; being an Extension of Mr. JOHN SEWELL'S "Treatise on Steam." By D. KINNEAR CLARK, M.I.C.E. Second Edition, revised. 3s. 6d.; cloth boards, 4s.

PLUMBING: a Text-book to the Practice of the Art or Craft of the Plumber. With Chapters upon House Drainage, *embodying* the latest improvements. Third Edition, enlarged. *With 300 Illustrations.* By W. P. BUCHAN. 3s. 6d.; cl. boards, 4s.